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ABSTRACT

The full texts of the five major papers presented at the Singapore seminar comprise the body of this conference report. The seminar was jointly sponsored by the Academy for Educational Development (AED) and the Southeast Asian Ministers of Education Organization's (SEAMEO) Regional Center for Educational Innovation and Technology (INNOTECH): its purpose was to familiarize educators and educational managers of the SEAMEO countries with a film and handbook produced by AED which was designed to provide administrators with the information they need to make policy decisions on the introduction of educational technology into school systems. Individual papers deal with the following topics: 1) systems and educational technology; 2) new developments in the United States in educational technology; 3) the individual's role as educational innovator and change agent; 4) sub-systems of national educational systems; and 5) the application of educational communications technologies in developing countries. (Author/PB)

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SEAMEO REGIONAL CENTER FOR
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SEAMEO REGIONAL INNOTECH CENTER
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FOREWORD

The Academy for Educational Development (AED), a non profit educational research and consulting organisation in Washington D.C. has produced a film and handbook which intends to be primarily concerned "with what administrators need to know before they can make new policy decisions on the introduction of educational technology into a school system."

INNOTECH learned about this film and handbook project and felt that they would be of great interest to educators and educational managers of the region. The Center kept in touch with AED through regular correspondence, and in April 1972, on the suggestion of AED, the AED/INNOTECH Seminar was held in Singapore.

The entire INNOTECH staff and 40 programme participants attended the Seminar. The programme participations were from the 8 SEAMEO countries; each country delegation was asked to give a brief report on the use of educational technology in its country, mainly for the information of the AED team.

In his brief welcome address Mr. Ly Chanh Duc, INNOTECH Director, said that the field of educational technology had become one of the most talked about disciplines in recent years. Numerous studies and research works had been done in this field, and the AED product, i.e., the handbook and film on educational technology, to be presented at this Seminar, might constitute a major step forward in the right direction.

Mr. Duc then introduced the members of the AED team, Mr. Sidney Tickton, Executive Vice President, Dr. James G. Miller, Vice President, and Dr. Jerry G. Short, Associate Professor, University of Virginia. Dr. Short had been with INNOTECH a year earlier in the capacity of Director of Research and Training. The purpose of this Seminar was to (1) review, discuss and evaluate the AED handbook and film on Educational Technology, and (2) to elicit advice and suggestions from AED about the consonance of INNOTECH's activities with AED's stated objectives.

INNOTECH wishes to thank the AED representatives most sincerely for their participation in the Seminar, and for the film and handbook which have been made available for use at the Center. Their Seminar papers are reproduced in the pages that follow.

PRESENTATION OF PAPERS

SYSTEMS AND EDUCATIONAL TECHNOLOGY

By Dr. James G. Miller, Vice President,
Academy for Educational Development,
Washington, D.C.

It is remarkable how the same problems concerning the application of instructional technology have turned up in this conference in the reports from the eight participant nations which we have heard turn up in other parts of the world. Though there are, of course, cultural differences, the issues are fundamentally the same.

First of all, the question arises as to what is instructional technology? We must agree that it includes both hardware, software, and the entire systems approach. The term "systems approach" has been used repeatedly throughout this conference, and always with approval and support. There are some questions, however, as to whether we are all using this term in the same sense. There are certainly many different concepts of the word "system" in common usage, and much confusion among systems theorists and systems analysts as to the appropriate way to use the term.

We have been doing research on general systems theory for more than 20 years, and it may be helpful at this point to take some time to consider what is the nature of living systems.

General systems theory is a set of related definitions, assumptions, and propositions which deal with reality as an integrated hierarchy of organizations of matter and energy. General systems behavior theory is concerned with a special subset of all systems, the living ones.

Even more basic to this presentation than the concept of "systems" are the concepts of "space," "time," "matter," "energy," and "information," because the living systems discussed here exist in space and are made of matter and energy organized by information.

1. Space and time

In the most general mathematical sense, a space is a set of elements which conform to certain postulates. The conceptual spaces of mathematics may have any number of dimensions.

Physical space is the extension surrounding a point. Classically the three dimensional geometry of Euclid was considered to describe accurately all regions in physical space. The modern general theory of relativity has shown that physical space-time is more accurately described by a geometry of four dimensions, three of space and one of time.

This presentation of a general theory of living systems will employ two sorts of spaces in which they may exist, physical or geographical space and conceptual or abstracted spaces.

1.1 Physical or geographical space. This will be considered as Euclidean space, which is adequate for the study of all aspects of living systems as we now know them. Among the characteristics and constraints of physical space are the following: (a) From point A to point B is the same distance as from point B to point A. (b) Matter or energy moving on a straight or curved path from point A to point B must pass through every intervening point on the path. This is true also of markers bearing information. (c) In such space there is a maximum speed of movement for matter, energy, and markers bearing information. (d) Objects in such space exert gravitational pull on each other. (e) Solid objects moving in such space cannot pass through one another. (f) Solid objects moving in such space are subject to friction when they contact another object.

The characteristics and constraints of physical space affect the action of all concrete systems, living and nonliving. The following are some examples: (a) On the average, people interact more with persons who live near to them in a housing project than with persons who live far away in the project. (b) The diameter of the fuel supply lines laid down behind General Patton's advancing American Third Army in World War II determined the amount of friction the lines exerted upon the fuel pumped through them to supply Patton's tanks. This was one physical constraint which limited the rate at which the army could advance, because they had to halt when they ran out of fuel. (c) Today information can flow worldwide almost instantly by telegraph, radio, and television. In the Seventeenth Century it took weeks for messages to cross an ocean. A government could not send messages so quickly to its ambassadors then as it can now because of the constraints on the rate of movement of the marker bearing the information. Consequently ambassadors of that century had much more freedom of decision than they do now.

Physical space is a common space, for the reason that it is the only space in which all concrete systems, living and nonliving, exist (though some may exist in other spaces simultaneously). Physical space is shared by all scientific observers, and all scientific data must be collected in it. This is equally true for natural science and behavioral science. Most people learn that physical space exists, which is not true of many spaces I shall mention in the next section. They can give the location of objects in it.

1.2 Conceptual or abstracted spaces. Scientific observers often view living systems as existing in spaces which they conceptualize or abstract from the phenomena with which they deal. Examples of such spaces are: (a) Peck order in birds or other animals. (b) Social class space (lower lower, upper lower, lower middle, upper middle, lower upper, and upper upper classes). (c) Social distance among ethnic or racial groups. (d) Political distance among political parties of the right and the left. (e) Sociometric space, e.g., the rating on a scale of leadership ability of each member of a group by every other member. (f) A space of time costs of various modes of transportation, e.g., travel taking longer on foot than by air, longer upstream than down.

These conceptual and abstracted spaces do not have the same characteristics and are not subject to the same constraints as physical space. Each has characteristics and constraints of its own. These spaces may be either conceived of by a human being or learned about from others. Interpreting the meaning of such spaces, observing relations, and measuring distances in them ordinarily require human observers. Consequently the biases of individual human beings color these observations.

Social and some biological scientists find conceptual or abstracted spaces useful because they recognize that physical space is not a major determinant of certain processes in the living systems they study. E.g., no matter where they enter the body, most of the iodine atoms in the body accumulate in the thyroid gland. The most frequent interpersonal relations occur among persons of like interests or like attitudes rather than among geographical neighbors. Families frequently come together for holidays no matter how far apart their members are. Allies like England and Australia are often more distant from each other in physical space than they are from their enemies.

It is desirable that scientists who make observations and measurements in any space other than physical space should attempt to indicate precisely what are the transformations from their space to physical space. Other spaces are definitely useful to science, but physical space is the only common space in which all concrete systems exist.

1.3 Time. This is the fundamental "fourth dimension" of the physical space-time continuum. Time is the particular instant at which a structure exists or a process occurs, or the measured or measurable period over which a structure endures or a process continue. For the study of all aspects of living systems as we know them, for the measurement of durations, speeds, rates, and accelerations, the usual absolute scales of time -- seconds, minutes, days, years -- are adequate. A concrete system can move in any direction on the spatial dimensions, but only forward -- never backward -- on the temporal dimension.

2. Matter and energy

Matter is anything which has mass (m) and occupies physical space. Energy (E) is defined in physics as the ability to do work. The principle of the conservation of energy states that energy can be neither created nor destroyed in the universe, but it may be converted from one form to another, including the energy equivalent of rest-mass. Matter may have (a) kinetic energy, when it is moving and exerts a force on other matter; (b) potential energy, because of its position in a gravitational field; or (c) rest-mass energy, which is the energy that would be released if mass were converted into energy. Mass and energy are equivalent. One can be converted into the other in accordance with the relation that rest-mass energy is equal to the mass times the square of the velocity of light. Because of the known relationship between matter and energy, throughout this chapter the joint term matter-energy is used except where one or the other is specifically intended. Living systems require matter-energy, needing specific types of it, in adequate amounts. Heat, light, water, minerals, vitamins, foods, fuels, and raw materials of various kinds, for instance, may be required. Energy for the processes of living systems is derived from the breakdown of molecules (and, in a few recent cases, of atoms as well). Any change of state of matter-energy or its movement over space, from one point to another, is action. It is one form of process.

3. Information

Throughout this presentation information (H) will be used in the technical sense first suggested by Hartley in 1928, and later developed by Shannon in his mathematical theory of communication. It is not the same thing as meaning or quite the same as information as we usually understand it. Meaning is the significance of information to a system which processes it: it constitutes a change in that system's processes elicited by the information, often resulting from associations made to it on previous experience with it. Information is a simpler concept: the degrees of freedom that exist in a given situation to choose among signals, symbols, messages, or patterns to be transmitted. The total of all these possible categories (the alphabet) is called the ensemble. The amount of information is measured by the binary digit, or bit of information. It is the amount of information which relieves the uncertainty when the outcome of a situation with two equally likely alternatives is known. Legend says the American Revolution was begun by a signal to Paul Revere from Old North Church steeple. It could have been either one or two lights "one if by land or two if by sea." If the alternatives were equally probable, the signal conveyed only one bit of information, resolving the uncertainty in a binary choice. But it carried a vast amount of meaning, meaning which must be measured by other sorts of units than bits.

The term marker refers to those observable bundles, units, or changes of matter-energy whose patterning bears or conveys the informational symbols from the ensemble or repertoire. These might be the stones of Hannurabi's day which bore cuneiform writing, parchments, writing paper, Indians' smoke signals, a door key with notches, punched cards, paper or magnetic tape, a computer's magnetized ferrite core memory, an arrangement of nucleotides in a DNA molecule, the molecular structure of a hormone, pulses on a telegraph wire, or waves emanating from a radio station. The marker may be static, as in a book or in a computer's memory. Communication of any sort, however, required that the marker move in space, from the transmitting system to the receiving system, and this movement follows the same physical laws as the movement of any sort of matter-energy. The advance of communication technology over the years has been in the direction of decreasing the matter-energy costs of storing and transmitting the markers which bear information. The efficiency of information processing can be increased by lessening the mass of the markers, making them smaller so they can be stored more compactly and transmitted more rapidly and cheaply. Over the centuries engineering progress has altered the mode in markers from stones bearing cuneiform to magnetic tape bearing electrons, and clearly some limit is being approached.

In recent years systems theorists have been fascinated by the new ways to study and measure information flows, but matter-energy flows are equally important. Systems theory deals both with information theory and with energetics — such matters as the muscular movements of people, the flow of raw materials through societies, or the utilization of energy by brain cells.

It was noted above that the movement of matter-energy over space, action, is one form of process. Another form of process is information processing or communication, which is the change of information from one state to another or its movement from one point to another over space. Communications, while being processed, are often shifted from one matter-energy state to another, from one sort of marker to another. If the form of pattern of the signal remains relatively constant during these changes, the information is not lost. For instance, it is now possible to make a chest X ray, storing the information on photographic film; then a photo-scanner can pass over the film line by line, from top to bottom, converting the signals to pulses in an electrical current which represent bits; then those bits can be stored in the core memory of a computer; then those bits can be processed by the computer so that contrasts in the picture pattern can be systematically increased; then the resultant altered patterns can be printed out on a cathode ray tube and photographed. The pattern of the chest structures, the information, modified for easier interpretation, has remained largely invariant throughout all this processing from one sort of marker to another. Similar transformations go on in living systems.

One basic reason why communication is of fundamental importance is that informational patterns can be processed over space and the local matter-energy at the receiving point can be organized to conform to, or comply with, this information. As already stated, if the information is conveyed on a relatively small, light, and compact marker, little energy is required for this process. Thus it is a much more efficient way to accomplish the result than to move the entire amount of matter-energy, organized as desired, from the location of the transmitter to that of the receiver. This is the secret of success of the delivery of "flowers by telegraph." It takes much less time and human effort to send a telegram from one city to another requesting a florist in the latter place to deliver flowers locally, than it would to drive or fly with the flowers from the former city to the latter.

Shannon was concerned with mathematical statements describing the transmission of information in the form of signals or messages from a sender to a receiver over a channel such as a telephone wire or a radio band. These channels always contain a certain amount of noise. In order to convey a message, signal in channels must be patterned and must stand out recognizably above the background noise.

Matter-energy and information always flow together. Information is always borne on a marker. Conversely there is no regular movement in a system unless there is a difference in potential between two points, which is negative entropy or information. Which aspect of the transmission is most important depends upon how it is handled by the receiver. If the receiver responds primarily to the material or energic aspect, it is a matter-energy transmission; if the response is primarily to the information, it is an information transmission. For example, the banana eaten by a monkey is a non-random arrangement of specific molecules, and thus has its informational aspect, but its use to the monkey is chiefly to increase the energy available to him. So it is an energy transmission. The energic character of the signal light that tells him to depress the lever which will give him a banana is less important than the fact that the light is part of a nonrandom, patterned organization which conveys information to him. So it is an information transmission. Moreover, just as living systems must have specific forms of matter-energy, so they must have specific patterns of information. For example, some species of animals do not develop normally unless they have appropriate information inputs in infancy. Harlow showed, for instance, that monkeys cannot make proper social adjustment unless they interact with other monkeys during a period between the third and sixth months of their lives.

4. System

The term system has a number of meanings. There are systems of numbers and of equations, systems of value and of thought, systems of law, solar systems, organic systems, management systems, command and control systems, electronic systems, even the Union Pacific Railroad system. The meanings of "system" are often confused. The most general, however, is: A system is a set of interacting units with relationships among them. The word "set" implies that the units have some common properties, which is essential if they are to interact or have relationships. The state of each unit is constrained by, conditioned by, or dependent on the state of other units.

4.1 Conceptual system.

4.1.1 Units. Units of a conceptual system are terms, such as words (commonly nouns, pronouns, and their modifiers), numbers, or other symbols, including those in computer simulations and programs.

4.1.2 Relationships. A relationship of a conceptual system is a set of pairs of units, each pair being ordered in a similar way. E.g., the set of all pairs consisting of a number and its cube is the cubing relationship. Relationships are expressed by words (commonly verbs and their modifiers), or by logical or mathematical symbols, including those in computer simulations and programs, which represent operations, e.g., inclusion, exclusion, identity, implication, equivalence, addition, subtraction, multiplication, or division. The language, symbols, or computer programs are all concepts and always exist in one or more concrete systems, living or nonliving, like a scientist, a textbook, or a computer.

4.2 Concrete system.

A concrete system is a nonrandom accumulation of matter-energy, in a region in physical space-time, which is organized into interacting interrelated subsystems or components.

4.2.1 Units. The units (subsystems, components, parts, or members) of these systems are also concrete systems.

4.2.2 Relationships. Relationships in concrete systems are of various sorts, including spatial, temporal, spatiotemporal, and causal.

Both units and relationships in concrete systems are empirically determinable by some operation carried out by an observer. In theoretical verbal statements about concrete systems, nouns, pronouns, and their modifiers typically refer to concrete systems, subsystems, or components; verbs and their modifiers usually refer to the relationships among them. There are numerous examples, however, in which this usage is reversed and nouns refer to patterns of relationships or processes, such as "nerve impulse," "reflex," "action," "vote," or "annexation."

4.2.3 Open system. Most concrete systems have boundaries which are at least partially permeable, permitting sizeable magnitudes of at least certain sorts of matter-energy or information transmissions to cross them. Such a system is an open system. Such inputs can repair system components that break down and replace energy that is used up.

4.2.4 Closed system. A concrete system with impermeable boundaries through which no matter-energy or information transmissions of any sort can occur is a closed system. No actual concrete system is completely closed, so concrete systems are either relatively open or relatively closed. Whatever matter-energy happens to be within the system is all there is going to be. The energy gradually is used up and the matter gradually becomes disorganized. A body in a hermetically sealed casket, for instance, slowly crumbles and its component molecules become intermingled. Separate layers of liquid or gas in a container move toward random distribution. Gravity may prevent entirely random arrangement.

4.2.5 Nonliving system. Every concrete system which does not have the characteristics of a living system is a nonliving system.

4.2.6 Living systems. The living systems are a special subset of the set of all possible concrete systems, composed of the plants and the animals. They all have the following characteristics:

(a) They are open systems.

(b) They use inputs of foods or fuels to restore their own organized structure.

(c) They have more than a certain minimum degree of compl

(d) They contain genetic material composed of deoxyribonucleic acid (DNA), presumably descended from some primordial DNA common to all life, or have a charter, or both. One or both of these is the template — the original "blueprint" or "program" — of their structure and process from the moment of their origin.

(e) They are largely composed of protoplasm including proteins and other characteristic organic compounds.

(f) They have a decider, the essential critical subsystem which controls the entire system, causing its subsystems and components to interact.

(g) They also have certain other specific critical subsystems or they have symbiotic or parasitic relationships with other living or nonliving systems which carry out the processes of any such subsystem they lack.

(h) Their subsystems are integrated together to form actively self-regulating, developing, reproducing unitary systems, with purposes and goals.

(i) They can exist only in a certain environment. Any change in their environment of such variables as temperature, air pressure, hydration, oxygen content of the atmosphere, or intensity or radiation outside a relatively narrow range which occurs on the surface of the earth, produces stresses to which they cannot adjust. Under such stresses they cannot survive.

4.3 Abstracted system.

4.3.1 Units. The units of abstracted systems are relationships abstracted or selected by an observer in the light of his interests, theoretical viewpoint, or philosophical bias. Some relationships may be empirically determinable by some operation carried out by the observer, but others are not, being only his concepts.

4.3.2 Relationships. The relationships mentioned above are observed to inhere and interact in concrete, usually living, systems. In a sense, then, these concrete systems are the relationships of abstracted systems. The verbal usages of theoretical statements concerning abstracted systems are often the reverse of those concerning concrete systems: the nouns and their modifiers typically refer to relationships and the verbs and their modifiers (including predicates) to the concrete systems in which these relationships inhere and interact. These concrete systems are empirically determinable by some operation carried out by the observer. A theoretical statement oriented to concrete systems typically would say "Lincoln was President," but one oriented to abstracted systems, concentrating on relationships or roles, would very likely be phrased "The Presidency was occupied by Lincoln."

An abstracted system differs from an abstraction, which is a concept (like those that make up conceptual systems) representing a class of phenomena all of which are considered to have some similar "class characteristic." The members of such a class are not thought to interact or be interrelated, as are the relationships in an abstracted system.

Abstracted systems are much more common in social science theory than in natural science.

Parsons has attempted to develop general behavior theory using abstracted systems. To some a social system is something concrete in space-time, observable and presumably measurable by techniques like those of natural science. To Parsons the system is abstracted from this, being the set of relationships which are the form of organization. To him the important units are classes of input-output relationships of subsystems rather than the subsystems themselves.

4.4 Abstracted vs. concrete systems. One fundamental distinction between abstracted and concrete systems is that the boundaries of abstracted systems may at times be conceptually established at regions which cut through the units and relationships in the physical space occupied by concrete systems, but the boundaries of these latter systems are always set at regions which include within them all the units and internal relationships of each systems.

A science of abstracted systems certainly is possible and under some conditions may be useful. When Euclid was developing geometry, with its practical applications to the arrangement of Egyptian real estate, it is probable that the solid lines in his figures were originally conceived to represent the borders of land areas or objects. Sometimes, as in Figure 1, he would use dotted "construction lines"

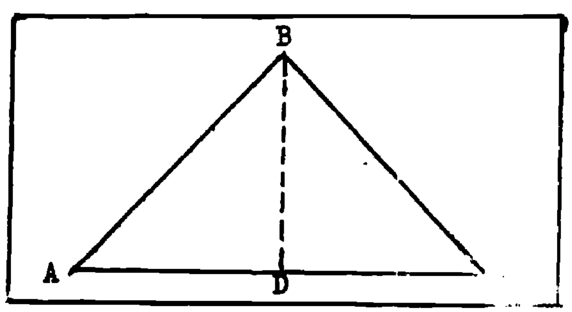


Figure 1. A Euclidean Fi

to help conceptualize a geometric proof. The dotted line did not correspond to any actual border in space, Triangle ABD would be shown to be congruent to Triangle CBD, and therefore the angle BAD was equal to the angle BCD. After the proof was completed, the dotted line might well be erased, since it did not correspond to anything real and was useful only for the proof. Such construction lines, representing relationships among real lines, were used in the creation of early forms of abstracted systems.

If the diverse fields of science are to be unified, it would help if all disciplines were oriented either to concrete or to abstracted systems. It is of paramount importance for scientists to distinguish clearly between them. To use both kinds of systems in theory leads to unnecessary problems. It would be best if one type of system or the other were generally used in all disciplines.

All three meanings of "system" are useful in science, but confusion results when they are not differentiated. A scientific endeavor may appropriately begin with a conceptual system and evaluate it by collecting data on a concrete or on an abstracted system, or it may equally well first collect the data and then determine what conceptual system it fits. Throughout this paper the single word "system," for brevity, will always mean "concrete system." The other sorts of systems will always be explicitly distinguished as either "conceptual system" or "abstracted system."

5. Structure

The structure of a system is the arrangement of its subsystems and components in three-dimensional space at a given moment of time. This always changes over time. It may remain relatively fixed for a long period or it may change from moment to moment, depending upon the characteristics of the process in the system. This process halted at any given moment, as when motion is frozen by a high-speed photograph, reveals the three-dimensional spatial arrangement of the system's components as of that instant.

6. Process

All change over time of matter-energy or information in a system is process. If the equation describing a process is the same no matter whether the temporal variable is positive or negative, it is a reversible process; otherwise it is irreversible. Process includes the on-going function of a system, reversible actions succeeding each other from moment to moment. Process also includes history, less readily reversed changes like mutations, birth, growth, development, aging, and death; changes which commonly follow trauma or disease; and the changes resulting from learning which are not later forgotten. Historical processes alter both the structure and the function of the system. The statement "less readily reversed" has been used instead of "irreversible" (although many such changes are in fact irreversible) because structural changes sometimes can be reversed: a component which has developed and functioned may atrophy and finally disappear with disuse; a functioning part may be chopped off a hydra and regrow. History, then, is more than the passage of time. It involves also accumulation in the system of residues or effects of past events (structural changes, memories, and learned habits). A living system carries its history with it in the form of altered structure, and consequently of altered function also. So there is a circular relation among the three primary aspects of systems -- structure changes momentarily with functioning, but when such change is so great that it is essentially irreversible, a historical process has occurred, giving rise to a new structure.

7. Type

If a number of individual living systems are observed to have similar characteristics, they often are classed together as a type. Types are abstractions. Nature presents an apparently endless variety of living things which man, from his earliest days, has observed and classified -- first, probably, on the basis of their threat to him, their susceptibility to capture, or their edibility, but eventually according to categories which are scientifically more useful. Classification by species is applied to organisms, plants or animals, or to free-living cells, because of their obvious relationships by reproduction. These systems are classified together by taxonomists on the basis of likeness of structure and process, genetic similarity and ability to interbreed, and local interaction, often including, in animals, ability to respond appropriately to each other's signs.

There are various types of systems at other levels of the hierarchy of living systems besides the cell and organism levels, each classed according to different structural and process taxonomic differentia. There are, for instance, primitive societies, agricultural societies, and industrial societies. There are epithelial cells, fibroblasts, red blood cells, and white blood cells, as well as free-living cells.

8. Level

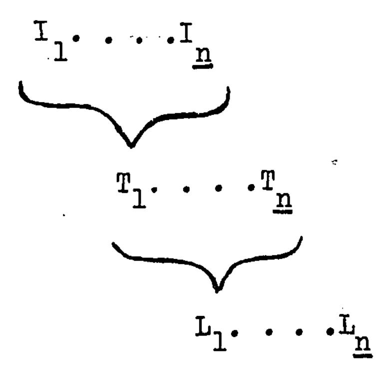
The universe contains a hierarchy of systems, each higher level of system being composed of systems of lower levels. Atoms are composed of particles; molecules, of atoms; crystals and organelles, of molecules. About at the level of crystallizing viruses, like the tobacco mosaic virus, the subset of living systems begins. Viruses are necessarily parasitic on cells, so cells are the lowest level of living systems. Cells are composed of atoms, molecules, an multi-molecular organelles; organs are composed of cells aggregated into tissues; organisms, of organs; groups (e.g., herds, flocks, families, teams, tribes), of organisms; organizations, of groups (and sometimes single individual organisms); societies of organizations, groups, and individuals; and supranational systems, of societies and organizations. Higher levels of systems may be of mixed composition, living and non-living. They include planets, solar systems, galaxies, and so forth. It is beyond the scope of this paper to deal with the characteristics -- whatever they may be -- of systems below and above those levels which include the various forms of life, although others have done so. The subset of living systems includes cells, organs, organisms, groups, organizations, societies, and supranational systems.

It would be convenient for theorists if the hierarchial levels of living systems fitted neatly into each other like Chinese boxes. The facts are more complicated. No one can argue that there are exactly these seven levels, no more and no less. For example, one might conceivably separate tissue and organ into two separate levels. Or one might maintain that the organ is not a level, since no organ exists that can exist independent of other organs.

What are the criteria for distinguishing any one level from the others? They are derived from a long scientific tradition of empirical observation of the entire gamut of living systems. This extensive experience of the community of scientific observers has led to a consensus that there are certain fundamental forms of organization of living matter-energy. Indeed the classical division of subject-matter among the various disciplines of the life or behavioral sciences is implicitly or explicitly based upon this consensus.

It is important to follow one procedural rule in systems theory, in order to avoid confusion. Every discussion should begin with an identification of the level of reference, and the discourse should not change to another level without a specific statement that this is occurring. Systems at the indicated level are called systems. Those at the level above are suprasystems, and at the next higher level, <u>suprasuprasystems</u>. Below the level of reference are <u>subsystems</u>, and below them subsubsystems. For example, if one is studying a cell, its organelles are the subsystems, and the tissue or organ is its suprasystem, unless it is a free-living cell whose suprasystem includes other living systems with which it interacts.

<u>8.1 Intersystem generalization</u>. A fundamental procedure in science is to make generalizations from one system to another on the basis of some similarity between the systems, which the observer sees and which permits him to class them together. For example, since the Nineteenth Century, the field of "individual differences" has been expanded, following the tradition of scientists like Galton in anthropometry and Binet in psychometrics. In Figure 2, states of separate specific individual systems on a specific structural or process variable are represented by I_1 to I_n. For differences among such individuals to be observed and measured, of course, a variable common to the type, along which there are individual variations, must be recognized (T_1). Physiology depends heavily, for instance, upon the fact that individuals of the type (or species) of living organisms called cats are fundamentally alike, even though minor variations from one individual to the next are well recognized.



<u>Figure 2. Individual, Type, Level.</u>

Scientists may also generalize from one type to another (T_1 to T_n). An example is cross-species generalization, which has been commonly accepted only since Darwin. It is the justification for the labors of the white rat in the cause of man's understanding of himself. Rats and cats, cats and chimpanzees, chimpanzees and human beings are similar in structure, as comparative anatomists know, and in function, as comparative physiologists and psychologists demonstrate.

The amount of variance among species is greater than among individuals within a species. If the learning behavior of cat Felix is compared with that of mouse Mickey, we would expect not only the sort of individual differences which are found between Mickey and Minnie Mouse, but also greater species differences. Cross-species generalizations are common, and many have good scientific acceptability, but in making them interindividual and interspecies differences must be kept in mind. The learning rate of men is not identical to that of white rats, and no man learns at exactly the same rate as any others.

The third type of scientific generalization indicated in Figure 2 is from one level to another. The basis for such generalization is the assumption that each of the levels of life, from cell to society, is composed of systems of the previous lower level. These cross-level generalizations will, ordinarily, have greater variance than the other sorts of generalizations, since they include variance among types and among individuals. But they can be made, and they can have great conceptual significance.

That there are important uniformities, which can be generalized about, across all levels of living systems is not surprising. All are composed of comparable carbon-hydrogen-nitrogen constituents, most importantly a score of amino acids organized into similar proteins, which are produced in nature only in living systems. All are equiped to live in a water-oxygen world rather than, for example, on the methane and ammonia planets so dear to science fiction. Also they are all adapted only to environments in which the physical variables, like temperature, hydration, pressure, and radiation, remain within relatively narrow ranges. Moreover, they all presumably have arisen from the same primordial genes or template, diversified by evolutionary change. Perhaps the most convincing argument for the plausibility of cross-level generalization derives from analysis of this evolutionary development of living systems. Although increasingly complex types of living systems have evolved at a given level, followed by higher levels with even greater complexity, certain basic necessities did not change. All these systems, if they were to survive in their environment, had, by some means or other, to carry out the same vital subsystem processes. While free-living cells, like protozoans, carry these out with relative simplicity, the corresponding processes are more complex in multicellular organisms like mammals, and even more complex at higher levels. The same processes are "shredded out" to multiple components in a more complex system, by the sort of division of labor which Parkinson has made famous as a law. This results in formal identities across levels of systems, more complex subsystems at higher levels carrying out the same fundamental processes as simpler subsystems at lower levels.

A formal identity among concrete systems is demonstrated by a procedure composed of three logically independent steps: (a) recognizing an aspect of two or more systems which has comparable status in those systems; (b) hypothesizing a quantitative identity between them; and (c) demonstrating that identity within a certain range of error by collecting data on a similar aspect of each of the two or more systems being compared. It may be possible to formulate some useful generalizations which apply to all living systems at all levels. A comparison of systems is complete only when statements of their formal identities are associated with specific statements of their interlevel, intertype, and interindividual disidentities. The confirmation of formal identities and disidentities is done by research.

What makes interindividual, intertype, or interlevel formal identities among systems important and of absorbing interest, is that -- if they can be conslusively demonstrated -- very different structures, which carry out similar processes, may well turn out to carry out acts so much alike that they can be quite precisely described by the same formal model. Conversely, it may perhaps be shown as a general principle that subsystems with comparable structures but quite different processes may have quantitative similarities as well.

8.2 Emergents. The more complex systems at higher levels manifest characteristics, more than the sum of the characteristics of the units, not observed at lower levels. These characteristics have been called "emergents." Significant aspects of living systems at higher levels will be neglected if they are described only in terms and dimensions used for their lower-level subsystems and components.

A clear-cut illustration of emergents can be found in a comparison of three electronic systems. One of these -- wire connecting the poles of a battery -- can only conduct electricity, which heats the wire. Add several tubes, condensers, resistors, and controls, and the new system can become a radio, capable of receiving sound messages. Add dozens of other components, including a picture tube and several more controls, and the system becomes a television set which can receive sound and a picture. And this is not just more of the same. The third system has emergent capabilities the first system did not have, emergent from its special design of much greater complexity. But there is nothing mystical about the colored merry-go-round and racing children on the TV screen — it is the output of a system which can be completely explained by a complicated set of differential equations such as electrical engineers write, including terms representing the characteristics of each of the set's components.

9. Echelon

This concept may seem superficially similar to the concept of level, but is distinctly different. Many complex living systems, at various levels, are organized into two or more echelons (in the military sense of a step in the "chain of command," not in the other military sense of arrangement of troops in rows in physical space). In living systems with echelons the components of the decider, the decision-making subsystem, are hierarchically arranged so that usually certain types of decisions are made by one component of that subsystem and others by another. Each is an echelon. All echelons are within the boundary of the decider subsystem. Ordinarily each echelon is made up of components of the same level as those which make up every other echelon in that system. Characteristically the decider component at one echelon gets information from a source or sources which process information primarily or exclusively to and from that echelon. It may be that at some levels of living systems — e.g., cells — there are no cases in which the decider is organized in echelon structure.

After a decision is made at one echelon on the basis of the information received, it is transmitted, often through a single subcomponent which may or may not be the same as the decider, but possibly through more than one subcomponent, upward to the next higher echelon, which goes through a similar process, and so on to the top echelon. Here a final decision is made and then command information is transmitted downward to lower echelons. Characteristically information is abstracted or made more general as it proceeds upward from echelon to echelon and it is made more specific or detailed as it proceeds downward. If a given component does not decide but only passes on information, it is not functioning as an echelon. In some cases of decentralized decision-making, certain types of decisions are made at lower echelons and not transmitted to higher echelons in any form, while information relevant to other types of decisions is transmitted upward. If there are multiple parallel deciders, without a hierarchy that has subordinate and superordinate deciders, there is not one system but multiple ones.

10. Suprasystem

10.1 Suprasystem and environment. The suprasystem of any living system is the next higher system in which it is a component or subsystem. For example, the suprasystem of a cell or tissue is the organ it is in; the suprasystem of an organism is the group it is in at the time. Presumably every system has a suprasystem except the "universe." The suprasystem is differentiated from the environment. The immediate environment is the suprasystem minus the system itself. The entire environment includes this plus the suprasuprasystem and the systems at all higher levels which contain it. In order to survive the system must interact with and adjust to its environment, the other parts of the suprasystem. These processes alter both the system and its environment. Living systems adapt to their environment, and in return mold it. The result is that, after some period of interaction, each in some sense becomes a mirror of the other.

10.2 Territory. The region of physical space occupied by a living system, and frequently protected by it from an invader, is its territory. Examples are a bowerbird's stage, a dog's yard, a family's property, a nation's land.

11. Subsystem and component

In every system it is possible to identify one sort of unit, each of which carries out a distinct and separate process, and another sort of unit, each of which is a discrete, separate structure. The totality of all the structures in a system which carry out a particular process is a subsystem. A subsystem, thus, is identified by the process it carries out. It exists in one or more identifiable structural units of the system. These specific, local, distinguishable structural units are called components or members or parts. Reference has been made to these components in the definition of a concrete system as "a nonrandom accumulation of matter-energy, in a region in physical space-time, which is organized into interacting, interrelated subsystems or components." There is no one-to-one relationship between process and structure. One or more processes may be carried out by two or more components. Every system is a component, but not necessarily a subsystem of its suprasystem. Every system is a component, but bot necessarily a subsystem of its suprasystem. Every component that has its own decider is a system at the next lower level, but many subsystems are not systems at the next lower level, being dispersed to several components.

The concept of subsystem process is related to the concept of role used in social science. Organization theory usually emphasizes the functional requirements of the system which the subsystem fulfills, rather than the specific characteristics of the component or components that make up the subsystem. The typical view is that an organization specifies clearly defined roles (or subsystem processes) and human beings "fill them." But it is a mistake not to recognize that characteristics of the component — in this case the person carrying out the role — also influence what occurs. A role is more than simple "social position," a position in some social space which is "occupied." It involves interaction, adjustments between the component and the system. It is a multiple concept, referring to the demands upon the component by the system, to the internal adjustment processes of the component, and to know the component functions in meeting the system's requirements. The adjustments it makes are frequently compromises between the requirements of the component and the requirements of the system.

The way living systems develop does not always result in a neat distribution of exactly one subsystem to each component. The natural arrangement would appear to be for a system to depend on one structure for one process. But there is not always such a one-to-one relationship. Sometimes the boundaries of a subsystem and a component exactly overlap, are congruent. Sometimes they are not congruent. There can be (a) a single subsystem in a single component; (b) multiple subsystems in a single component; (c) a single subsystem in multiple components; or (d) multiple subsystems in multiple components.

Systems differ markedly from level to level, type to type, and perhaps somewhat even from individual to individual, in their patterns of allocation of various subsystem processes to different structures. Such process may be (a) localized in a single component; (b) combined with others in a single component; (c) dispersed laterally to other components in the system; (d) dispersed upward to the suprasystem or above; (e) dispersed downward to subsubsystems or below; or (f) dispersed to other systems external to the hierarchy it is in. Which allocation pattern is employed is a fundamental aspect of any given system. For a specific subsystem function in a specific system one strategy results in more efficient process than another. One can be better than another in maximizing effectiveness and minimizing costs. Valuable studies can be made at each level on optimal patterns of allocation of processes to structures. In all probability there are general systems principles which are relevant to such matters. Possible examples are: (a) Structures which minimize the distance over which matter-energy must be transported or information transmitted are the most efficient. (b) If multiple components carry out a process, the process is more difficult to control and less efficient than if a single component does it. (c) If one or more components which carry out a process are outside the system, the process is more difficult to integrate than if they are all in the system. (d) Or if there are duplicate components capable of performing the same process, the system is less vulnerable to stress and therefore is more likely to survive longer, because if one component is inactivated, the other can carry out the process alone.

11.1 Critical subsystem. Certain processes are necessary for life and must be carried out by all living systems that survive or be performed from them by some other system. They are carried out by the following critical subsystems listed in Table 1.

Matter-Energy Processing Subsystems	Subsystems Which Process Both Matter-Energy and Information	Information Processing Subsystems
	Reproducer	
	Boundary	
Ingestor		Input Transducer
		Internal Transducer
Distributor		Channel and Net
Converter		Decoder
Producer		Associator
Matter-Energy Storage		Memory
		Decider
		Encoder
Extruder		
Motor		Output Transducer
Supporter		

Table 1. The Critical Subsystems.

The definitions of the critical subsystems are as follows:

11.1.1 Subsystems which process both matter-energy and information.

Reproducer, the subsystem which is capable of giving rise to other systems similar to the one it is in.

Boundary, the subsystem at the perimeter of a system that holds together the components which make up the system, protects them from environment stresses, and excludes or permits entry to various sorts of matter-energy and information.

11.1.2 Matter-energy processing subsystems.

Ingestor, the subsystem which brings matter-energy across the system boundary from the environment.

Distributor, the subsystem which carries inputs from outside the system or outputs from its subsystems around the system to each component.

Converter, the subsystem which changes certain inputs to the system into forms more useful for the special processes of that particular system.

Producer, the subsystem which forms stable associations that endure for significant periods among matter-energy inputs to the system or outputs from its converter, the materials synthesized being for growth, damage repair, or replacement of components of the system, or for providing energy for moving or constituting the system's outputs of products or information markers to its suprasystem.

Matter-energy storage, the subsystem which retains in the system, for different periods of time, deposits of various sorts of matter-energy.

Extruder, the subsystem which transmits matter-energy out of the system in the forms of products and wastes.

Motor, the subsystem which moves the system or parts of it in relation to part or all of its environment or moves components of its environment in relation to each other.

Supporter, the subsystem which maintains the proper spatial relationships among components of the system, so that they can interact without weighting each other down or crowding each other.

11.1.3 Information processing subsystems.

Input transducer, the sensory subsystem which brings markers bearing information into the system, changing them to other matter-energy forms suitable for transmission within it.

Internal transducer, the sensory subsystem which receives, from all subsystems or components within the system, markers bearing information about significant alterations in those subsystems or components, changing them to other matter-energy forms of a sort which can be transmitted within it.

Channel and net, the subsystem composed of a single route in physical space, or multiple interconnected routes, by which markers bearing information are transmitted to all parts of the system.

Decoder, the subsystem which alters the code of information input to it through the input transducer or the internal transducer into a "private" code that can be used internally by the system.

Associator, the subsystem which carries out the first stage of the learning process, forming enduring associations among items of information in the system.

Memory, the subsystem which carries out the second stage of the learning process, storing various sorts of information in the system for different periods of time.

Decider, the executive subsystem which receives information inputs from all other subsystems and transmits to them information outputs that control the entire system.

Encoder, the subsystem which alters the code of information inputs to it from other information processing subsystems, from a "private" code used internally by the system into a "public" code which can be interpreted by other systems in its environment.

Output Transducer, the subsystem which puts out markers bearing information from the system, changing markers within the system into other matter-energy forms which can be transmitted over channels in the system's environment.

Of these critical subsystems only the decider is essential, in the sense that a system cannot be dependent on another system for its deciding. A living system does not exist if the decider is dispersed upwardly, downwardly, or outwardly.

Since all living systems are genetically related, have similar constituents, live in closely comparable environments, and process matter-energy and information, it is not surprising that they should have comparable subsystems and relationships among them. All systems do not have all possible kinds of subsystems. They differ individually, among types, and across levels, as to which subsystems they have and the structures of those subsystems. But all living systems either have a complement of the critical subsystems carrying out the functions essential to life or are intimately associated with and effectively interacting with systems which carry out the missing life functions for them.

<u>11.2 Inclusion</u>. Sometimes a part of the environment is surrounded by a system and totally included within its boundary. Any such thing not a part of the system's own living structure is an <u>inclusion</u>. Any living system at any level may include living or nonliving components. The amoeba, for example, ingests both inorganic and organic matter and may retain particles of iron or dye in its cytoplasm for many hours. A surgeon may replace an arteriosclerotic aorta with a plastic one and that patient may live comfortably with it for years. To the two-member group of one dog and one cat an important plant component is often added -- one tree. An airline firm may have as an integral component a computerized mechanical system for making reservations which extends into all its offices. A nation includes many sorts of vegetables, minerals, buildings, and machines, as well as its land.

The inclusion is a component or subsystem of the system if it carries out or helps in carrying out a critical process of the system; otherwise it is part of the environment. Either way the system, to survive, must adjust to its characteristics. If it is harmless or inert it can often be left undisturbed. But if it is potentially harmful -- like a pathogenic bacterium in a dog or a Greek in the giant gift horse within the gates of Troy -- it must be rendered harmless or walled off or extruded from the system or killed. Because it moves with the system in a way the rest of the environment does not, it constitutes a special problem. Being inside the system it may be a more serious or more immediate stress than it would be outside the system's protective boundary. But also, the system that surrounds it can control its physical actions and all routes of access to it. For this reason international law has developed the concept of extraterritoriality to provide freedom of action to ambassadors and embassies, nations' inclusions within foreign countries.

<u>11.3 Artifact</u>. An artifact is an inclusion in some system, made by animals or man. Spider webs, bird nests, beaver dams, houses, books, machines, music, paintings, and language are artifacts. They

may or may not be <u>prostheses</u>, inventions which carry out some critical process essential to a living system. An artificial pacemaker for a human heart is an example of an artifact which can replace a pathological process with a healthy one. Insulin and thyroxine are replacement drugs which are human artifacts. Chemical, mechanical, or electronic artifacts have been constructed which carry out some functions of all levels of living systems.

Living systems create and live among their artifacts. Beginning presumably with the hut and the arrowhead, the pot and the vase, the plow and the wheel, mankind has constructed tools and devised machines. The Industrial Revolution of the Nineteenth Century, capped by the recent harnessing of atomic energy, represents the extension of man's matter-energy processing ability, his muscles. A new Industrial Revolution, of even greater potential, is just beginning in the Twentieth Century, with the development of information and logic-processing machines, adjuncts to man's brain. These artifacts are increasingly becoming prostheses, relied on to carry out critical subsystem processes. A chimpanzee may extend his reach with a stick; a man may extend his cognitive skills with a computer. Today's prostheses include input transducers which sense the type of blood cells that pass before them and identify missiles that approach a nation's shores; photographic, mechanical, and electronic memories which can store masses of information over time; computers which can solve problems, carry out logical and mathematical calculations, make decisions, and control other machines; electric typewriters, high speed printers, cathode ray tubes, and photographic equipment which can output information. An analysis of many modern systems must take into account the novel problems which arise at man-machine interfaces.

Music is a special sort of human artifact, an information-processing artifact. So are the other arts and cognitive systems which people share. So is language. Whether it be a natural language or the machine language of some computer system, it is essential to information processing. Often stored only in human brains and expressed only by human lips, it can also be recorded on nonliving artifacts like stones, books, and magnetic tapes. It is not of itself a concrete system. It changes only when man changes it. As long as it is used it is in flux, because it must remain compatible with the ever-changing living systems that use it. But the change emanates from the users, and without their impact the language is inert. The artifactual language used in any information transmission in a system determines many essential aspects of that system's structure and process.

12. Transmissions in concrete systems

All process involves some sort of transmission among subsystems within a system, or among systems. There are inputs across the boundary into a system, internal processes within it, and outputs from it. Each of these sorts of transmissions may consist of either (a) some particular form of matter; (b) energy, in the form of light, radiant energy, heat, or chemical energy; or (c) some particular pattern of information.

13. Steady state

When opposing variables in a system are in balance, that system is in equilibrium with regard to them. The equilibrium may be static and unchanging or it may be maintained in the midst of dynamic change. Since living systems are open systems, with continually altering fluxes of matter-energy and information, many of their equilibria are dynamic and are often referred to as flux equilibria or steady states. These may be unstable, in which a slight disturbance elicits progressive change from the equilibrium state — like a ball standing on an inverted bowl; or stable, in which a slight disturbance is counteracted so as to restore the previous state — like a ball in a cup; or neutral, in which a slight disturbance makes a change, but without cumulative effects of any sort — like a ball on a flat surface with friction.

All living systems tend to maintain steady states (or homeostasis) of many variables, keeping an orderly balance among subsystems which process matter-energy or information. Not only are subsystems usually kept in equilibrium, but systems also ordinarily maintain steady states with their environments and suprasystems, which have outputs to the systems and inputs from them. This prevents variations in the environment from destroying systems. The variables of living systems are constantly fluctuating, however. A moderate change in one variable may produce greater or lesser alterations in other related ones. These alterations may or may not be reversible.

13.1 Stress, strain, and threat. There is a range of stability for each of the numerous variables in all living systems. It is that range within which the rate of correction of deviations is minimal or zero, and beyond which correction occurs. An input or output of either matter-energy or information, which by lack or excess of some characteristic, forces the variables beyond the range of stability, constitutes stress and produces a strain (or strains) within the system. Input lack and output excess both produce the same strain — diminished amounts in the system. Input excess and output lack both produce the opposite strain — increased amounts. Strains may or may not be capable of being reduced, depending upon their intensity and the resources of the system. The totality of the strains within a system resulting from its template program and from variations in the inputs from its environment can be referred to as its values. The relative urgency of reducing each of these specific strains represents its hierarchy of values.

Stress may be anticipated. Information that a stress is imminent constitutes a threat to the system. A threat can create a strain. Recognition of the meaning of the information of such a threat must be based on previously stored (usually learned) information about such situations. A pattern or input information is a threat when -- like the odor of the hunter on the wind; a change in the acidity of fluids around a cell; a whirling cloud approaching the city -- it is capable of eliciting processes which can counteract the stress it presages. Processes -- actions or communications -- occur in systems only when a stress or a threat has created a strain which pushes a variable beyond its range of stability. A system is a constantly changing cameo and its environment is a similarly changing bas-relief, and the two at all times fit each other. That is, outside stresses or threats are mirrored by inside strains. Matter-energy storage and memory also mirror the past environment, but with certain alterations.

13.1.1 Matter-energy stress. There are various ways for systems to be stressed. One class of stresses is the matter-energy stresses, including: (a) matter-energy input lack or underload -- starvation or inadequate fuel input; (b) input of an excess of overload of matter-energy; and (c) restraint of the system, binding it physically. (This may be the equivalent of (a) or (b).)

13.1.2 Information stress. Also there are information stresses, including: (a) information input lack or underload, resulting from a dearth of information in the environment or from improper function of the external sense organs or input transducers; (b) injection of noise into the system, which has an effect of information cut-off, much like the previous stress; (c) information input excess or overload. Informational stresses may involve changes in the rate of information input or in its meaning.

13.2 Adjustment processes. Those processes of subsystems which maintain steady states in systems, keeping variables within their ranges of stability despite stresses, are adjustment processes. In some systems a single variable may be influenced by multiple adjustment processes. As Ashby has pointed out, a living system's adjustment processes are so coupled that the system is ultrastable. This characteristic can be illustrated by the example of an army cot. It is made of wires, each of which would break under a 300-pound weight, yet it can easily support a sleeper of that weight. The weight is applied to certain wires, and as it becomes greater, first nearby links and then those farther and farther away, take up part of the load. Thus a heavy weight which would break any of the component wires alone can be sustained. In a living system, if one component cannot handle a stress, more and more others are recruited to help. Eventually the entire capacity of the system may be involved in coping with the situation.

13.2.1 Feedback. The term feedback means that there exist two channels, carrying information, such that Channel B loops back from the output to the input of Channel A and transmits some portion of the signals emitted by Channel A (see Figure 3). These are tell-tales or monitors of the outputs of Channel A. The transmitter on Channel A is a device with two inputs, formally represented by a function with two independent variables, one the signal to be transmitted on Channel A and the other a previously transmitted signal fed back on Channel B. The new signal transmitted on Channel A is selected to decrease the strain resulting from any error or deviation in the feedback signal from a criterion or comparison reference signal indicating the state of the output of Channel A which the system seeks to maintain steady. This provides control of the output of Channel A on the basis of actual rather than expected performance.

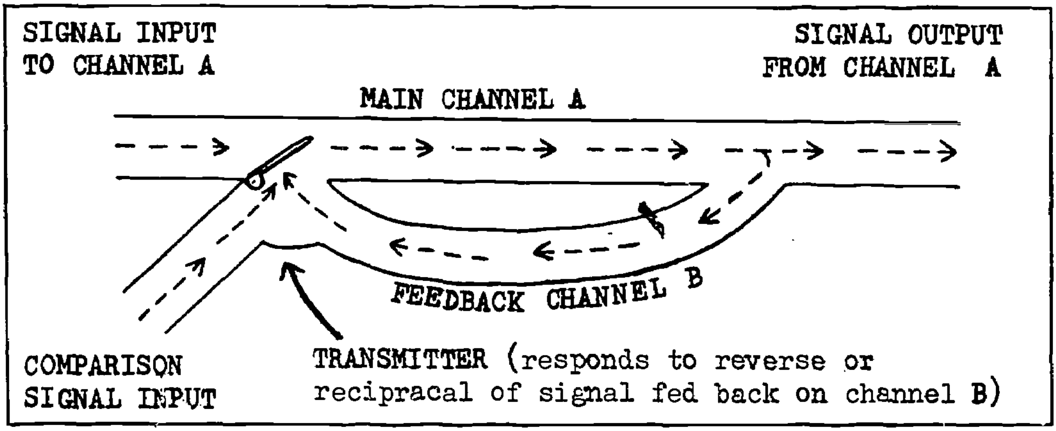


Figure 3. Negative Feedback

When the signals are fed back over the feedback channel in such a manner that they increase the deviation of the output from a steady state, positive feedback exists. When the signals are reversed, so that they decrease the deviation of the output from a steady state, it is negative feedback. Positive feedback alters variable and destroys their steady states. Thus it can initiate system changes.

Unless limited, it can alter variables enough to destroy systems. At every level of living systems numerous variables are kept in a steady state, within a range of stability, by negative feedback controls. When these fail, the structure and process of the systems does not survive. Feedback control always exhibits some oscillation and always has some lag. When the organism maintains its balance in space, this lag is caused by the slowness of transmissions in the nervous system, but is only of the order of hundredths of seconds. A social institution, like a corporation, may take hours to correct a breakdown in an assembly line, days or weeks to correct a bad management decision. In a society the lag can sometimes be so great that, in effect, it comes too late. General staffs often plan for the last war rather than the next. Governments receive rather slow official feedbacks from the society at periodic elections. They can, however, get faster feedbacks from the press, other mass media, picketers, or demonstrators. Public opinion surveys can accelerate the social feedback process. The speed and accuracy of feedback have much to do with the effectiveness of the adjustment processes they mobilize.

13.2.2 Power. In relation to energy processing, power is the rate at which work is performed, work being calculated as the product of a force and the distance through which it acts. The term also has another quite different meaning. In relation to information processing, power is control, the ability of one "master" system to influence in a specific direction the decision of a "slave" system at the same or another level, to elicit compliance from it. The system influenced may be the system itself -- a man may be his own master; it may be some subsystem or component of it; it may be its suprasystem; or it may be some external system at any level. Characteristically, in hierarchies of living systems, each level has a certain autonomy and to a degree is controlled by levels above and below it. A mutual "working agreement" thus is essential.

13.2.3 Purpose and goal. By the information input of its charter or genetic input, or by changes in behavior brought about by rewards and punishments from its suprasystem, a system develops a preferential hierarchy of values that gives rise to decision rules which determine its preference for one internal steady state value rather than another. This is its purpose. It is the comparison value which it matches to information received by negative feedback in order to determine whether the variable is being maintained at the appropriate steady state value. In this sense it is normative. The system then takes one alternative action rather than another because it appears most likely to maintain the steady state. When disturbed, his state is restored by the system by successive approximations, in order to relieve the strain of the disparity recognized internally between the feedback signal and the comparison signal. Any system may have multiple purposes simultaneously.

A system may also have an external goal, such as reaching a target in space, or developing a relationship with any other system in the environment. Or it may have several goals at the same time. Just as there is no question that a rat in a maze is searching for the goal of food at its end or that the Greek people under Alexander the Great were seeking the goal of world conquest. As Ashby notes, natural selection permits only those systems to continue which have goals that enable them to survive in their particular environments. The external goal may change constantly, as when a hunter chases a moving fox or a man searches for a wife by dating one girl after another, while the internal purpose remains the same.

A system's hierarchy of values determines its purposes as well as its goals. It is not difficult to distinguish purposes from goals, as the terms have been used: an amoeba has the purpose of maintaining adequate energy levels and therefore it has the goal of ingesting a bacterium; a boy has the purpose of keeping his body temperature in the proper range and so he has the goal of finding and putting on his sweater; Switzerland had the purpose in 1938 of remaining uninvaded and autonomous and so she sought the goal of a military organization which could keep all combatants outside her borders or disarm them if they crossed them.

13.2.4 Costs and efficiency. All adjustment processes have their costs, in energy of nonliving or living systems, in material resources, in information (including in social systems a special form of information often conveyed on a marker of metal or paper money), or in time required for an action. Any of these may be scarce. (Time is a scarcity for mortal living systems.) Any of these is valued if it is essential for reducing strains. The costs of adjustment processes differ from one to another and from time to time. They may be immediate or delayed, short-term or long-term.

How successfully systems accomplish their purpose can be determined if those purposes are known. A system's efficiency, then, can be determined as the ratio of the success of its performance to the costs involved. A system constantly makes economic decisions directed toward increasing its efficiency by improving performance and decreasing costs. Economic analyses of cost-effectiveness are in recent years frequently aided by program budgeting. This involves keeping accounts separately for each subsystem or component that carries out a distinct program. The matter-energy, information, money and time costs of the program are in such analyses compared with various measures of the efficiency of performance of the program. How efficiently a system adjusts to its environment is determined by what strategies it employs in selecting adjustment processes and whether they satisfactorily reduce strains without being too costly. This decision process can be analyzed by a mathematical approach to economic decisions, game theory. This general theory concerning the best strategies for weighing "plays" against "pay-offs," selecting actions which will increase profits while decreasing losses, increase rewards while decreasing punishments, improve adjustments of variables to appropriate steady state values, or attain goals while diminishing costs. Relevant information available to the decider can improve such decisions. Consequently such information is valuable. But there are costs to obtaining such information. Hurley has developed a mathematical theory on how to calculate the value of relevant information in such decisions. This depends on such considerations as whether it is tactical (about a specific act) or strategic (about a policy for action); whether it is reliable or unreliable, overtly or secretly obtained, accurate, distorted, or erroneous.

14. Conclusion

This analysis of living systems uses concepts of thermodynamics, information theory, cybernetics, and systems engineering, as well as the classical concepts appropriate to each level. The purpose is to produce a description of living structure and process in terms of input and output, flows through systems, steady states, and feedbacks, which will clarify and unify the facts of life. Future papers will indicate how these systems concepts can be applied to a particular class of living systems -- educational systems. Particular attention will be devoted to the application of program budgeting and cost-efficiency analysis to educational planning and administration. Emphasis will also be placed on the potential of a particular class of artifacts -- the new information processing technologies -- for improving the quality and efficiency of educational programs and cutting their costs.

The following is an outline of the rest of Dr. Miller's presentation:

The first industrial revolution, which began to develop intensively about 1800 and continues until today has been a development of artifacts to help individual man or societies at large to process matter and energy more effectively. The second industrial revolution, which began about 25 years ago is the application of new information

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?
1. Class lecture	No	No	No	No	Rarely
2. Small discussion group	No	No	No	No	Sometimes
3. Books and journals	Yes	Yes	Yes	Yes, unless another user has it	Yes
4. Printed programmed instruction	Yes	Yes	Yes	Yes	Yes
5. Computerized programmed instruction	No	Yes	Rarely	Yes, unless number of terminals is limited	Yes
6. On-line computer aids to learning & scholarship	No	Yes	Rarely	Yes, unless number of terminals is limited	Yes
7. Closed-circuit lectures on public address system	No	No	No	No	No
8. Educational radio	No	Yes	Yes	Nc	No
9. Dial-access audio tape recordings	No	Yes	Rarely	Yes	In some systems
10. Broadcast live instructional TV	No	Yes	Sometimes	No	No
11. Closed-circuit live instructional TV	No	Yes	No	No	No
12. Broadcast tape-recorded instructional TV	No	Yes	Sometimes	No	No*
13. Closed-circuit tape recorded instructional TV	No	Yes	No	No	No*
14. Dial-access instructional TV	No	Yes	No	Yes, unless number of terminals is limited	Sometimes
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
16. Automated storage & retrieval of written & graphic materials	No	Yes	Rarely	Yes	Yes
17. Other standard audiovisual aids	Usually	Yes	Often	Yes	Yes

Table 1. Characteristics and Costs of Various Instructional Media

Instructional Medium	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	Vision & Audition	No	0.15-3
2. Small discussion group	Yes	Rarely	Vision & Audition	No	0.50-15
3. Books and journals	No	No	Vision	No	0.05-10
4. Printed programmed instruction	No	Yes	Vision	No	0.05-10
5. Computerized programmed instruction	Yes	Yes	Vision & Audition	Yes	2-25
6. On-line computer aids to learning & scholarship.	Yes	Yes	Vision	Yes	5-100
7. Closed-circuit lectures on public address system	No	No	Audition	Yes	0.02-2
8. Educational radio	No	No	Audition	Yes	0.01-1
9. Dial-access audio tape recordings	Rarely	No	Audition	Yes	0.01-2
10. Broadcast live instructional TV	No*	No	Vision & Audition	Yes	0.02-10
11. Closed-circuit live instructional TV	No*	No	Vision & Audition	Yes	0.03-3
12. Broadcast tape-recorded instructional TV	No*	No	Vision & Audition	Yes	0.01-5
13. Closed-circuit tape recorded instructional TV	No*	No	Vision & Audition	Yes	0.03-2
14. Dial-access instructional TV	Rarely	No	Vision & Audition	Yes	0.50-5
15. Facsimile transmission of documents by electronic circuits	No	No	Vision	Yes	2-15
16. Automated storage & retrieval of written & graphic materials	Sometimes	Yes	Vision	Yes	2-100
17. Other standard audiovisual aids	Sometimes	Rarely	Vision & Audition	No	0.05-8

Table 1. (Continued)

processing artifacts to help an individual or the society at large process information more effectively. Automobiles, airplanes, and guns are some of the products of the first industrial revolution. Computers for computer data instruction and television are some of the artifacts of the second industrial revolution. It is important that educators give serious consideration as to the potential application to education of the products both of the first and of the second industrial revolution. In doing this the emphasis should be on the individual student and the creating of the environment about him necessary for optimal learning. This can be done either by human beings exclusively or by information processing artifacts, or by some combination of the two.

Cost effectiveness or cost benefits must be taken into consideration at all times. One should not throw up his hands and give no consideration to the possibility of using the information processing technology just because the costs seem to be too great. Rather careful analysis should be made of costs and benefits of alternative technologies in the given situation. Then recommendation should be made in terms of a realistic appraisal of the funds available. This may require some increase in the percentage of the gross national product of the nation devoted to education, which may mean a decrease to some extent of the amount devoted to other purposes. Because of the great employments of education and creating a base for national development, however, this may be justified.

All nations today are suffering from the fact that research in the field of education throughout the world has been weak as compared with other aspects of the natural behavioral sciences. Educators have found it hard to agree upon the objectives of training programs. They have found it difficult to develop reliable and objective measures of the educational process which can be used for evaluation. They have not set up the educational experiments using scientific control methods with evaluation methods which have been planned and arranged in advance. They have not used a method of comparing objectively alternative systems, considering all the media. A very primitive chart analysing some of the aspects of the various media which may make them effective and estimating very roughly the ranges of costs appears below:

Education throughout the world, both in developing and established nations, is labor intensive. Teachers, like all other workers, will fight change if it means, or if they think it means, that they are going to lose their jobs. This is a problem of the introduction of all forms of technological advances which involve automation of functions that were previously carried out by human beings. It is important to deal with this form of resistance by planning over a period of five or ten years, how to take advantage of personnel turnover or the growth of demand for education to phase in new technological approaches without causing any present employees to lose their jobs. Resistance to such changes will be greatly diminished if all current employees know that none of them will be caused to lose their jobs as a result of the innovations.

Sharing of resources should be a major emphasis. SEAMEO is an excellent example of such sharing among several nations. Sharing of resources may require translation of software from one language to another, but after the software is prepared, translation is usually relatively cheap. In addition to software, hardware resources may be shared among developing nations. For example, a factory for making hardware might be built in one of the eight Southeast Asian nations of SEAMEO, or it might be possible for a satellite to be deployed which would cover all of those countries. Also, as INNOTECH demonstrates, planning resources among nations in a given region can be coordinated.

It is also important to include in the education of all teachers information both about systems theory and the systems approach of evaluating alternative educational strategy should be emphasised as central to education. It should not be looked on as a relatively unimportant peripheral aspect, which is the frequent attitude.

There are many resistances to any form of change, and particularly in education there are strong resistances to the introduction of instructional technology. These have been discussed in the conference. It is important to recognize explictly that they exist and analyse strategies for dealing with them.

Maintenance problems of instructional technology should not be under-emphasized. For example, if a large number of television sets are ordered, parts for those sets should be ordered at the same time, and training programs for technicians should be set up if adequate numbers of technicians are not available. This is equally important if computers or other types of hardware are going to be used in instruction.

Computers are rapidly becoming more sophisticated and less expensive. They are available to some degree in all of the Southeast Asian nations. They can significantly improve information processing in education, and also, through management information systems, can cut costs and improve effectiveness of management. A major way for developing nations to cut the costs of education is to apply computerised management information systems to their operations.

In most cases when instructional technology has been employed, it is simply a part of a total educational reform. This is as it should be. Numerous examples can be pointed to where educational technology is clearly bringing about important educational innovations, even though in some of them it is still unclear what their effect on cost effectiveness really is.

As educators interested in educational innovation with instructional technology, we have a responsibility in our own country to try to change national priorities. We must continually emphasize to policy makers that improving the education of the population as a whole is an essential priority which must underly other forms of development. If practical and political considerations present us from undertaking immediately large scale applications of instructional technology to higher education, it is important for educators interested in these approaches at least to try to find enough funds to set up a well designed, limited experiment. There are many approaches to limitation of an experiment to a relatively small population which will still make it possible to initiate a small program. Once such a thing is started, history has shown that, if it appears effective, adequate support will be found to permit it to expand.

NEW DEVELOPMENTS IN EDUCATIONAL TECHNOLOGY IN THE UNITED STATES[1]

by Dr. Sidney G. Tickton

My assessment at the moment was to make some comments on new developments of educational technology and I thought I would do it rather broadly, bring to you such information as we know is available in the United States and around the world. One of the things that bothers me about conferences such as this is that we sometimes forget to bring to the conference the information, the background, and the discussions that have occurred in previous conferences. A few months ago, the Agency for International Development (AID) called together at a meeting of the Centre outside Washington D.C. a group of 40 or 50 people from around the world, to talk about the latest developments in educational technologies, and I thought I would make a quick summary of what happened at that meeting.

In that particular meeting, the objective was to direct attention to the major policy questions that were facing AID and other international funding agencies on the use of educational technology. And the questions that were raised for that meeting were what AID and the other agencies ought to be doing to expand the use of educational technology, and how they could get a better pay-off from the programmes that they were financing, and what they could do to make the programmes they now have more effective. These kinds of questions are always raised by funding agencies, whether they are international agencies such as the World Bank and the Asian Development Bank, or whether they are government groups like AID, or whether they are private foundations such as the Ford Foundation. I heard the same questions when I was at the Ford Foundation.

In developing the background for that conference, it was pointed out that much of the experimentation in educational technology has been the repeating of small scale efforts previously made by other researchers, teachers and administrators. Some of the repetitions have been due to lack of information concerning what has gone on previously, some of them due to the fact that people refused to use other people's experiences, some of them due to the fact that educational experimentation is costly, breaking new grounds is costly and time consuming and

(1) This presentation was made extemporaneously by Dr. Tickton. It is reproduced here from the recorded tapes, with slight editing by the INNOTECH staff.

if you are working in this field no one can give you any assurance that you are going to be successful. For the most part, as you all know, the efforts to apply modern educational technology and media to educational problems have resulted in reports that there have been no significant differences because we are not sure whether it is because of the programmes or whether it is because of our measurement devices. I would argue, for example, in the El Salvador project, that in order to determine whether you have achieved anything you would start with a subject such as English as a second language. If you wanted to have a base line to start from, you would start a year before you introduce the programme; at that point you would find that the achievements of the pupils were zero, because nobody was teaching English as a second language, so that out of a country of a couple of million people, there were only a dozen of places where you could find people who were speaking English as a second language. So that is the way the base line ought to be established. From the research point of view, that is biasing the results too much in favour of getting great big results. Thus, Dr. Wilbur Schramm in doing his testing would not use such a base line for his consideration, for his research, for his scientific approach; but from the approach of the people of a country the nett result was a substantial increase in the number of people who spoke English as a second language. Let's say at the end of two years, they have two thousand people and previously only had 50 people. So, as a result, there was a great achievement, but it doesn't show up in the achievement. The main thing that the experiments have been able to show, the small scale experiments,is that people do learn with modern communications media, that sometimes technology can make learning fun; and the one thing that has been true is that technology can permit changes to occur that had not otherwise been possible.

In the case of El Salvador, Korea, Samoa, Ivory Coast, there are dramatic changes in the content of the curriculum, and the people who were involved felt that this could not have happened without something dramatic to act as a lever. This was the price of getting change. Something had to happen. Nobody would have put in the time, effort and money if you did not have something dramatic to work with. After a period of 10 or 15 years working with educational television, educational radio, programmed instruction, computers and the simpler audio-visual devices, a considerable number of people have become interested in what is now commonly called the systems approach to educational improvement. The systems approach in education consists of six steps, of which the first is the pre-planning step, the second is the market research to find out who it is you are going to try to educate. The third step is teacher training, the fourth is curriculum development and the producing of the programmes. The fifth is evaluation, and the sixth is changing the programmes as a result of the evaluation. This kind of systematic approach to educational improvement has not been tried in a significant way in any place in the United States. We are frank to admit this, and we are also frank to say that many of the early experiments that were financed by the Ford Foundation failed to carry on. They achieved their immediate results, but they failed to carry on over a ten- or fifteen-year period, because the systematic approach to problems was not adopted. Moreover, there has been a heavy resistence to this type of a programme in the United States, because of the attitude of teachers who have felt that these kinds of steps, these kinds of educational technology would displace existing teachers, and they have succeeded over the years in refusing to adopt significant educational technology approaches as part of the educational programme. So, in this report that I gave you yesterday, that was prepared for the President's Commission on Instructional Technology, I felt very confident in saying (which I did two and a half years ago, and nobody has criticized it since) that educational technology represents a drop in the bucket, not more than 5% of the overall educational expenditures in the United States, that if in that country we had 16 million students going to school five days a week, and going to class five hours a day, for a total of a billion, two hundred and fifty million student class-hours, obviously not more than five or ten or fifteen million such hours were involved in any kind of situation other than the classroom and the teacher and the pupils, and there was no television, no films, no audio-visuals, nothing that represented either the use of modern communications media or any kind of programmed instruction beyond the teacher in the classroom.

Now, against this background of effort and experimentation and demonstration, the U.S. Congress has instructed AID to see whether communications technology could be used in any way to improve education, nutrition, family planning, agriculture in various countries, and this has been the basis upon which there have been many discussions during the past year. AID and many international organizations are looking for opportunities to combine all of the factors in the systems approach to produce useful learning experiences among students at a level of cost that developing countries can afford. This is a difficult point, because there is no question that things can be produced at a level of cost that you can't afford, how to do it at a level and a cost that people can afford in various parts of the world, is the unknown fact. But there is no doubt that over the next ten, fifteen, twenty years, there will be a considerable number of people working on these kinds of approaches, and there will be new combinations of hardware and software, and physical facilities and students, teachers, and financing, and maybe in some places some people will learn how to do things that work. But one way that obviously has got to be adopted, as Dr. Miller said, is much more sharing of resources, much more learning from other people's mistakes, and much more doing what it is possible to do with the resources at our hand.

On the other hand, no one could minimize the large essential costs, particularly on full scale projects, and the difficulty of transition from existing systems, and the difficulty of adding large numbers of people to an educational programme. In El Salvador, we are talking about increasing the number of people in the third and fourth and fifth grades, from maybe forty or fifty thousand to three or four hundred thousand, and we are thinking of doing the same thing in the Ivory Coast, and even more in Korea. Nobody has really paid attention to this kind of large scale problem, the physical problem of handling that many people, or the amount of time that is required to complete such a project with the transition which may be from five to ten years. And one of the problems is that many Ministries of Education have terms that last from one to three years, and they are not really in a position to undertake five to ten-year projects. This is also true of international agencies, AID and other government agencies. We are talking about the long terms. We are talking about difficult problems, and many of the people who are going to be involved have short-term objectives, short-term attitudes and this makes it more and more difficult.

At the Airlie House Conference, the participants wanted to know if we could list some of the characteristics that might merit joint efforts in the investment of the various agencies that are providing funds for educational technology experiments and so a number of these characteristics were listed. I thought you might find them interesting. One would be school systems using television, which rely less upon classroom teachers, provide more opportunity for rapid student progress, and substantially reduce the unit costs, not by reducing the number of teachers but by increasing the number of students substantially. This is the hope for an approach in the Ivory Coast and Korea. The number of students is expected to go up, say ten times, in countries that would be hard-put to double the number of teachers, just because there are not trained people available and they could not afford if they had the trained people available. But the objective here is to have a system that can have many more young people going through it with only a small increase in personnel and a great increase in the use of technology to help that personnel. In other words, this is just as you move in industrial societies by creating a factory and providing machinery and capital equipment, and a given number of personnel in the factory can turn out ten times as much product. This is an over-simplified example, but if many lesser developed countries are going to increase the number of people going to school without unduly burdening the budget, some ways have to be learned how to do this by using far less proportionate increase in personnel compared to increase in the number of students.

The second thing that was suggested is expanding the use of media other than television. The various combinations of media that hold some promise: educational radio, audio cassettes, micro fiches, various forms of programmed instruction, probably combined with television. People have not done too much with the various combinations, but possibilities are tremendous. There are, as you know, new types of hardware being produced: video discs and video tape recordings. The people who produced hardware say that there will be equipment that provides great opportunities in the future at relatively lower costs. We hope that this will work out.

The thing that you heard about last fall and has gained much popular attention in the past year, is the possibility of the other school learning activities. When I was at the Ford Foundation ten years ago, my associates were concerned about other school learning activities and independent study, but they got a deaf ear, nobody was paying attention. But the moment this is a wide possibility, lots of people are paying attention. As you know, Philip Coombs, who was at the International Institute of Educational Planning, is doing a report for the World Bank which is due in the next couple of months, and which will say, here are the various opportunities for the World Bank to invest in other school learning opportunities, and the World Bank hopes that much will occur as a result of his report. The one thing that is missing, and I say missing in much of the discussion about other school learning opportunities, is the fact that non-formal education does not necessarily mean inexpensive education, if one is expecting to have quality-type results. There is no reason to believe that it will necessarily work out, that if you want to teach, let's say English as a second language to a thousand people outside of the formal classroom, you could do it cheaper by radio or television at homes or offices or various places, rather than in some kind of classroom situation. There are people who talked casually about this, but it has not been proved; so I want to caution you in your discussion, to note that there are many possibilities, but that it is not necessarily true that they are going to be cheaper or better. One has to investigate and look very carefully.

Referring again to the Airlie House Conference in Washington, I am thinking about the other kinds of new developments in educational technology that are occurring in the United States and other parts of the world. There is a much greater willingness nowadays than there was three or four or five years ago to risk large amounts of money, time, energy and capital on new systems of education that can provide a given quality of education with fewer teachers per student, fewer buildings, greater learning in a shorter period of time, and learning new materials and techniques that have not been learned previously. As I mentioned several times yesterday, it is difficult to arrive at cost-benefit conclusions on educational technology that says this costs less than something else. However, if it could be shown that you could teach people the equivalent of what they would otherwise learn in three or four years or five years of schooling in, say, two years' time, using whatever combination that is possible, then one could argue that one has achieved a substantial cost-benefit result. In other words, you use the same quality of learning. There are few people who have tried this approach, but I think it is one that will develop much more substantially in the next few years, because there are people who have a pretty good idea of what they would like to have, and if the schooling period could be compressed so that it could be done quicker, this would be a great benefit to many countries. In some countries, if arrangements could be made by the use of technology to reduce the number of buildings that is required by the use of technology, much could be gained. But an even more important area is the learning of subjects that would not otherwise be possible: the learning of languages, the learning of vocational skills, the learning of various new items like the new biology, the new chemistry and the new math. Things would not be possible by the use of the people on hand. This could be a great benefit to the country, and there are many people working on these possibilities.

One other item with respect to the non-formal education idea is the extension of the approach at the college or university level in the United States. Within the past two years, a great deal of attention has been paid to off-campus programmes. Something along the line of what the University of London has been doing for many years, but which had not really been given much attention to in the United States, has suddenly blown up as an important educational possibility. It is not necessary for students at college age to spend so many weeks sitting in classrooms, doing such and such assignments and there are many ways of learning, and the college and university should pay attention to these possibilities. Within the past two years, dozens of university programmes have been created which allow for off-campus study, dozens of programmes have been created which will give credit for learning experiences achieved in ways other than going to college. Opportunities for people in foreign countries to receive US degrees based on some other experiences in very much less time than otherwise is required are being considered, and these are ways that would have been unconceivable as recently as four or five years ago. I mention this as an important development because in the definitions I used in the President's Commission, we are talking about educational technology as a process as well as hardware and software. There are many people interested in changing the process. How well it will work and how well it will turn out in the results, and what the test will show, remains yet to be seen. But an important development in the past 24 months is that educators who previously would not consider these possibilities are now giving them their endorsement and treating them very seriously.

Another new development which you keep hearing about and on which progress has been made, is the use of satellites for transmission of educational programmes. Clearly, the 1974 experiment with India and the 1975 experiment with Brazil would be important landmarks. Meantime, a big satellite project may develop in the United States which will involve the in-service training of teachers over hundreds of square miles. But people working on such programmes have discovered, as have people who have worked on television, computers and programmed instruction before, that it is reasonably early to get the satellite up as compared to providing a programme, that has got to go on the satellite. In the case of Brazil, for example, it is expected that there will be three hundred thousand separate receiving units; that there will be TV sets in the classrooms, or out in the community centres, or out in the individual teachers' houses, or out in the country side. But nobody knows how to handle educational programmes for three hundred thousand receiving centres, many of which have nothing in common except that they belong to the same country; and the country is thousands of miles square, thousands of miles across, and the people in the country side have no relationship at all with the people in the cities. What you put on the programmes that will be useful to all these various kinds of people certainly has not been worked out. Moreover, in a country such as India, this is an even greater problem where there are language barriers. At least in Brazil, it is all in Portuguese. In India, there are various language differences that complicate the problem. In any event, there are people working on this problem in great detail and it is an important new development in the past couple of years.

There are two other points that I would comment on. One is the use of educational technology, television on tapes, particularly video tapes, in industrial training in the United States. Corporations have found that they can take young people out of school, and start training them in their own companies to do the jobs that need to be done, whether they are technical engineering jobs or technician jobs or just secretarial jobs; that an important way of doing this is to develop tapes and programmed instruction materials and micro-teaching mechanisms, and so forth, which are efficient on a cost-benefit basis. For example, it has been found that by using tapes, one can teach a young lady to become a good typist in two weeks. She goes to the library, checks out the tapes that are scheduled for her twice a day, once in the morning and once in the afternoon. The tapes tell her precisely what to do. No teacher is involved. By the end of two weeks, she is a reasonably good typist. For a secretary, this takes maybe two months. But it is all done by audio tapes, maybe a little visual work, but mostly audio tapes. Industrial firms find these useful to them, so they proceed in this manner without going through a school system, but in many cases they represent some of the most dramatic advances, because from their point of view, this solves an important problem.

The last development that I wanted to mention is the attention being placed in the United States on the necessity for basic research in development education. As a result of the Commission of Instructional Technology's report in which we recommended a National Institute of Education, we were able to spring the idea, which was an old idea, from the backrooms of the colleges and universities to the desk of the President of the United States, at the time when he was looking for a useful idea. He submitted it to Congress, and Congress held hearings, and the bill has been passed by both-houses of the Congress. It is expected that in a year or two, a new National Institute of Education will be established in Washington which will be concerned with research and development and education, with the use of technology and new devices, and with the methods for achieving change. It will be something much more substantial than has ever been attempted in the past.

In the United States, as you know, there has been a large amount of research and development money that has gone into industry, gone into agriculture, and gone into the health fields and the health sciences. In 1954, as a result of the discovery of the SALK vaccine, the amount of money that went into health research was multiplied ten times in a couple of years, something like from a hundred million to a billion dollars from, say, 1951 to 1956 or 1957. This was all done by something called the National Institute of Health. As the National Institute of Education is patterned upon the same line, many hoped that similar types of funding will occur. We are not sure it will happen, but we hope it will occur sometime in the future. In any event, this is an important new development that bears watching. It will take some time to produce results, but anyway there is something that is being done.

I run into these things just because I thought they will be interesting to you. One of the problems in education throughout the world is communication; we need seminars and meetings such as this to bring people up-to-date as to what it is that we know that is going on and what you know that is going on and in the discussion and exchange of views at least we find out with each other those things we should be knowing, but the communication system is not as good as it should be. Thank you very much.

THE INDIVIDUAL AS AN EDUCATIONAL INNOVATOR AND CHANGE AGENT[1]

Jerry Short
University of Virginia

<u>What can one individual do to change the educational system of his country?</u>

Graduates of INNOTECH, and graduates of other centers of educational innovation and technology, face a difficult problem when they return home. The problem is this: how can they, as individuals. bring about educational innovation in their own countries?

During their training programs, these educators have learned about radical alternatives to traditional schooling, worked on large-scale projects, studied large-scale systems, and mastered many specific skills. But after training, most of the graduates return to jobs where they feel they cannot apply what they have learned. The These educators do not return home to become Prime Ministers or Ministers of Education, or even department chiefs who might have the power to initiate a systems study or finance a major innovation. Instead, they return to middle level jobs as school principals, teachers, supervisors, college lecturers, and officers in Ministries of Education.

Their frustration is summed up in this statement made by one graduate:

> "I've learned a lot of important things, but I am going back to my old job and my boss is a traditionalist. He is not going to let me try anything new. I am going to be unhappy doing things in the old way when I have learned some better ways of doing them. But I cannot do anything about it. I will not have any opportunity to innovate."

Even when graduates are more optimistic about their future, their plans are likely to be vague. For example, another graduate, when asked about what he would do after training, could only give this general answer:

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[1] A paper given at a seminar on Educational Technology held in Singapore, April 10-13, 1972. The seminar was sponsored by the Academy for Educational Development and the Southeast Asian Regional Center for Educational Innovation and Technology (INNOTECH).

"I'll try to do my best to help improve the standard of education in my country by using all the means in my power. It's very hard to say right now what I'll do later on."

What can one person do if he is the only innovator in a whole school district? What specific actions can one person perform by himself to bring about educational change? This article is about what he might do. It describes three objectives he could set for himself, and which he could use to evaluate his own progress as an innovator.

Objective 1. Become an important, well-known, useful expert on educational innovation and technology.

The newly graduated innovator should work to get other people to want his help. If he is successful in achieving this first objective, people in his country should say things like this about him:

"Before we go any further with this project, let's call him in. He has lots of information, good ideas, and he always thinks things can be done in better ways."

If the innovator overheard someone say this about him, he would know he had achieved the first objective.

But how does he become an important expert? The hardest thing about becoming an expert is getting started. Fortunately, he will have started already by participating in a special training program like the one at INNOTECH. And, when he returns home, people are going to ask him what he learned and what he did.

He should have two answers ready. One would be a formal talk prepared for groups. In it, he would define educational innovation and technology and show examples of how they can be used. He could prepare this while he was in training and use as many technological devices as possible: for example, behavioral objectives, illustrations, and tryouts. He could revise the talk until he could give it easily and naturally and until it achieved its desired effect.

The formal talk is one type of presentation the innovator should develop while he is in training. The other type is a conversational answer to a question a colleague might ask. For example:

Colleague: What did you do while you were in training?

Innovator: I got a lot of ideas about new approaches to education. I would like to use some of them. But first I have to identify our most important problems and needs. What do you think are our most important needs in education?

The innovator's answer attempts to do two things. First, it shows that the innovator has learned new concepts that he feels are important. Second, it shows that he is eager to listen to his colleague. By listening attentively, the innovator may learn a great deal, and he will convince his colleague that he is important. Probably, the best way to become an expert in someone else's eyes is to listen attentively to his ideas.

There are many other ways that the innovator can establish himself as an expert. Here are a few ideas:

- -- Translate or write articles about innovations in local languages.
- -- Volunteer to give a formal talk to any class or group that will listen.
- -- Search out people and listen to them as they talk about educational and national problems.
- -- Loan books, programs, and articles to interested people.
- -- Write reports for committees and work groups.

At this point in the presentation, the author stopped and asked the members of the audience to describe other ways that they could increase their own importance as educational experts in their own countries. They added these ideas:

- -- Volunteer to participate in in-service training programs to learn new ideas and share your own ideas.
- -- Meet periodically with other innovators, e.g., fellow graduates, board members, etc.
- -- Help others with their problems.
- -- Write papers on your own work and give them to others to read and make suggestions for improving them.
- -- Write articles analysing existing problems from a total systems point of view.
- -- Write a model lesson and publish it in an educational magazine.
- -- Read as much as possible about innovation and write about those innovations that it would be possible to implement in a particular country.

- Keep in touch with innovative centers and keep up-to-date on innovation and technology in education.
- Encourage others to attend courses on educational innovation and technology.
- Learn how to use and operate sophisticated educational media and equipment.
- Have the right questions to ask anyone who is advocating a particular reform or plan for education.

Let us now assume that by doing some of these things, the new innovator has achieved some importance and prestige as an expert. He must now begin to use his prestige to encourage innovation and change. This is not easy to do. Many people who have gained prestige and importance do not know how to use them to accomplish their goals. To do so, the innovator should establish a second objective for himself.

<u>Objective 2. Encourage innovators; ignore those who do not want to change</u>.

The new innovator should use his growing importance to encourage and reward those people who want to innovate and change. He can do this by paying attention to them, spending time with them, giving them ideas and support. At the same time, he should ignore those people who do not want to innovate and change. It is tempting to devote a lot of time to people who do not want to change by trying to convince them to change. But the innovator probably will not convince them by arguing with them, and he will find that he has no time left to help those people who want to change.

Some examples may make the second objective more explicit.

1. Which teacher should an innovator spend more time with?

   a. A poor teacher who resists his help.

   b. A good teacher who asks for help with a problem.

2. Which subordinate should the innovator spend more time with?

   a. One who says, "The new way will never work. The old way is better because we are all familiar with it."

   b. One who says, "I can see the advantage of the new way. Can you help me get started with it?"

In both examples, the innovator would make best use of his time working with the second person (b) and ignoring the first (a).

Objective 2 summarizes a general strategy for spreading successful innovation. The strategy was used last year in Singapore when an innovative primary curriculum was developed. The curriculum was made available on an optional basis, and teachers who wanted to use it were encouraged to do so. They were given training, assistance and encouragement. The other teachers who did not want to try the innovation were left alone. It appears that a successful innovation will spread quickly with little opposition when it is introduced in this way.

An authoritarian country can perhaps spread innovation in other ways. For example, Jerold L. Schuter reported in an article about China in Time (April 10, 1972, p.36) that when "asked what career aspirations they held for their sons, the Chinese invariably answered that the choice is up to the State. 'Whatever will serve the state will be good for my child.'" This innovation in career planning can be spread by authoritarian degree in China, but in other countries career planning for national growth can probably be introduced with more success by the other strategy. For example, the same goal could be achieved by introducing new additional opportunities in technical careers, and then encouraging and rewarding those students who choose the desired career paths.

The new innovator who has successfully accomplished Objectives 1 and 2 must still be aware of the danger of talking about innovation instead of doing it. The innovator, if he is to remain important, must produce something. Unfortunately, he will probably find it much easier to "talk" than to "do". He will meet many pessimists in education who will be anxious to discuss the impossibility of change. He should avoid these people or he may start imitating them. Instead he should choose action people as his models and associates. Working with them will challenge him to take action too. Thus, the third objective:

Objective 3. Take action; don't just talk.

Two examples will illustrate this objective.

1. Which is the better person for an innovator to work with?

   A. who says "We cannot begin until we analyze the problem for a year and consider the question of whether it is possible to write behavioral objectives for family planning."

   B. who says "Let's visit the staff of the Family Planning Board today and see if we can draft behavioral objectives for family planning."

The innovator should take a positive approach towards those who _try_ to innovate, even when they do not succeed. The innovator cannot expect perfect projects and products so he should encourage anyone who makes an attempt to change, even if the attempt is quite small and apparently insignificant. If the change is an improvement, no matter how small, the innovator should encourage it. Some more examples may illustrate this technique.

1. The members of a project staff have prepared some educational objectives. The innovator feels the objectives are better than the old ones, but he knows they are not as good as they could be. What should he say?

   a. "Your objectives need much more work. They are not stated in clear, behavioral terms. They are too vague. You have to be specific when you write objectives."

   b. "These objectives are a great improvement over the old ones because they are clearer and more specific. What do you plan to do with them next? Can I help?"

2. The innovator has been called in to evaluate a school. He finds that the teachers are using a new approach, but that they have no way of evaluating its success or failure. What should he say?

   a. "Your innovation is useless because you have no way to measure its effect. Unless you have an evaluation plan, you cannot tell if you are succeeding or failing."

   b. "I am very pleased to see how well all the teachers are using the new approach. It is unusual to find everyone so enthusiastic about trying something new. Can I help you develop some ways of evaluating the effectiveness of these new approaches?"

In the first answers (a), the innovator criticizes the obvious faults he has detected. In the second answers (b), he encourages those who have tried to change, and attempts to help them improve. It seems likely that the second approach will be more successful in maintaining interest in innovation, encouraging those who are trying to change, and making ideas for improving the innovation process more acceptable.

2. Which person is the better innovator?

A. who argues with his colleagues about the best version of the systems approach to use in planning and implementing innovation.

B. who prepares a game called "Our Spaceship Earth" to teach ecological concepts and evaluates the fame with a group of students.

In both examples, Person B seems to be accomplishing the third objective by taking action rather than just talking.

One difficulty with the advice to "take action" is that the problems to act on are often overwhelming. How can an individual innovator take action to solve the large important problems that are critical in most educational systems? He cannot. But he can work with a part of a problem and design an individual action project of his own to solve part of the problem. Here are some possibilities.

Individual Action Projects

New curriculum areas, such as population control, sex education, ecology, creative thinking, tutoring, career planning, moral development, managing money, etc., are good areas in which an innovator can create models to demonstrate applications of educational technology. For example, could an innovator sell a local newspaper on publishing a children's column with materials for readers to tutor non-readers? Or an educational comic strip? Or a column written by students?* Could he sell a local radio or TV station on the idea of short messages for students, each teaching them some simple but

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* An example was published in a Singapore newspaper during the seminar. In a letter to the editor of the Singapore Straits Times a student wrote: "I am a Secondary Four student and will be taking my Cambridge examination this year. Our foundation for mathematics is poor. Recently our mathematics teacher got into the habit of doing problems on the board without explanation and expected us to copy everything down into our exercise book. Although she gave us homework, she never checks our work. This means we will never know our mistakes. We have already used more than half of our exercise books, but haven't even checked a page of it. Although we know that she has to go for her lectures at the teachers' training college, but this doesn't mean that she can neglect her students." Probably several math teachers in Singapore revised their teaching methods after reading the letter!

important objectives? Could he prepare a short model lesson and show people how it works? Could the innovator prepare a simulation game, a role playing case, unit of programmed instruction, a film, a tape? Could he do something like an engineer in the U.S. did in his spare time when he developed a set of environmental projects for primary students to teach them the importance and fun of conserving the environment? Could the innovator write a test and give it to some students to find out if they are learning to think scientifically and rationally about their world? Could he get one teacher to try an organizational innovation in her classroom such as having students tutor other students in each-one-teach-one style?

At this point in the talk, the author stopped again and asked the audience to describe other individual action projects which they might undertake. These projects were mentioned:

-- Observe the behavior of children in different situations in the street to find out what they are learning and how we could take more advantage of natural learning situations.
-- Form an action group to revise our college syllabus, write objectives, and evaluate our work.
-- Tryout programs with my own children during my spare time. The next step, if the programs succeed, is to go to some school under my supervision and get them to try them.
-- Apply a systems approach to planning my own work.
-- Work out the costs and benefits of a plan to solve the problem of crowded schools by using alternate days of schools, e.g., half the students might attend school on Monday-Wednesday-Friday and the other half on Tuesday-Thursday-Saturday.
-- Conduct workshops in programmed instruction, systems approach, and writing behavioral objectives.
-- Teach a demonstration lesson before my colleagues in which I apply the systems approach by using objectives, pretests, and posttests.
-- Design a small project to discover what secondary students find most difficult to accomplish: problem solving, studying, listening, personal adjustment, etc.
-- Conduct studies to find ways of improving my own lectures and teaching.
-- Construct quiz sessions about various subject matters for TV or radio for groups of school children.
-- Prepare a restatement of instructional objectives now in use so that they are presented in measurable, life-use terms.
-- Use critical incidents from teachers as a resource for preparing role playing case studies for teacher training.

-- Conduct a simulation game with associates to help them apply a systems approach to a particular problem they are trying to solve.
-- Develop tests to identify specific weaknesses students have in some of my country's schools.
-- Hold week-end discussions with teachers within my province to get new ideas about innovations which they have tried.
-- Create a set of psychological experiments to teach principles of behavior to grade school students.

Summary

Three objectives for individual innovators have been described. These are the objectives that an individual innovator could work toward regardless of his job assignment.

1. Become a useful expert in educational innovation and technology.

2. Encourage innovators; ignore others who do not want to change.

3. Take action by starting your own individual action project.

There are many other objectives that an innovator could set as goals for himself. But these three alone should assure his success.

THE SUB-SYSTEMS OF A NATIONAL EDUCATIONAL SYSTEM AND A LIST OF A FEW CURRENT MAJOR EDUCATIONAL EXPERIMENTS USING INSTRUCTIONAL TECHNOLOGY*

Dr. James G. Miller
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According to general systems theory, there are seven levels of living system. In my first talk I emphasized the importance of the individual student, which is the organism level. In this talk I shall be talking about higher levels, educational organizations and the total national educational system. I should discuss these in terms of the list of matter, energy and information processing systems such as I presented to you in a chart during my first talk.

The reproducer sub-system of a society includes organizations which act to charter new organization of various sorts. INNOTECH is an example of this, since its effort is to reproduce modern educational systems of innovative types in the eight participating nations. Such reproductions is essential if new patterns of education are to be used widely.

Boundary. This sub-system frequently serves harmful as well as helpful functions. Among the harmful functions are those which prevent one school from cooperating with another and sharing resources. One nation, particularly nationalistic countries with languages and cultures differing from their neighbours, frequently do not cooperate effectively across their boundaries for comparable reasons. Conferences and joint programs involving interaction across boundaries tend to lessen these problems. So do language translation or the use of a common international language.

Distributor. When one is looking at a total national educational system, many other things besides information processing are important.

The effectiveness of transportation overroads, and by ship and other means within the country are important if hardware is to be employed, since all hardware needs servicing and these roads are critical for such purposes. For this reason the establishment of national programs using electronic instructional technology such as computers, television and radio are greatly facilitated if the road system is good. Similarly, the distribution of electricity throughout the country is important. If the country is entirely electrified, it is easy to operate electronic equipment. Otherwise battery sets must be used, there must be facilities for generating electricity to re-charge these batteries in some way.

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* An elaboration of this paper is reproduced on page 56 ff.

Supporter. Consideration should be given as whether funds should be devoted primarily to the building of new supporters for the educational system -- new school and college buildings, or whether instead of this skeleton of the educational system funding could better be applied to the internal nervous system -- the human or electronic channels and nets which carry the information which is the essence of education.

Input transducer. Living systems are more effective if they have significant free flow of information in and out of them. It is important that the educational system of one country be opened to the world as a whole, rather than turning in primarily on itself, paying attention primarily to information within the system.

Internal transducer. Systems operate more effectively if there is free flow of information not only downward from management or the decider sub-system, but also upwards from students, their parents, and their teachers, to tell management how well the system is operating and what improvements can be made.

Channel and net. Alternative channels and nets should be analysed from a costs-effectiveness basis. That is, human word-of-mouth communication should be compared with the use of books to transmit information, versus cassettes, both audio and video, versus radio, versus television, versus computer net works, versus satellites.

Decoder. If materials are not available in one language, the language spoken within the system, translation is necessary. Doing this make possible the sharing of resources over much wider areas, and is relatively inexpensive in time and money compared to the cost of developing materials entirely independently in each area where a new language is spoken.

Associator. This sub-system is the essence of education, which is based fundamentally on the learning process. There are many alternative ways to plan curriculum, phase in instruction, schedule it, arrange to test for it, and so on. Alternative plans should be studied systematically using careful evaluation methods and scientific controls.

Memory. In addition to the memory of individual students and teachers, there is society in memory of libraries. Important new developments in library methods which will greatly improve their effectiveness and ultimately cut costs, are now being developed and will be considered below.

Encoder. This sub-system is the reverse of the decoder, and it is clear that nations have responsibilities not only to translate the materials of others for their own use but to help others by translating materials produced within that country and for transmission to other nations.

Output transducer. Nations which have produced effective learning materials and hardware should tell the rest of the world about it, and this informing of the other nations can greatly contribute to this sharing of resources and the improvement of education on a worldwide basis.

A number of specific projects were then outlined illustrating, complex applications of instructional technology currently going on in the United States. These include:

The Pilot Medical School of Ohio State University, provides, through computer managed instruction, the first two years of Medical School to a selected group of Ohio State Medical students. It covers the entire basic medical science or pre-clinical curriculum.

At least 30 full courses are being given by the faculty of the university at Illinois living in Urbana by closed circuit television to the Chicago Circle campus of the same university, more than 100 miles away in Chicago.

Also at the Urbana campus of the University of Illinois Project PLATO is giving at least 200 full courses by computer aided instruction to a large number of students. A very large computer, the Illiac, is being used. Other campuses are becoming interested in connecting to the computer to use these materials.

EDUNET. This educational network idea was developed in 1966 and approved by the United States Congree, but funds have never been provided for it. Efforts, however, are being made to interconnect universities and colleges in the United States by a multi-media network for all the electronic media including libraries.

The Ohio College Library Council has developed an electronic system with remote terminals including a cathode ray tube and typewriter to more than 50 colleges and universities throughout the State of Ohio. The librarians of these colleges can use the terminal to converse with a computer in Columbus, Ohio, which tells them whether or not it has library catalogue cards prepared for any new book ordered by any library in the system. If so, the computer automatically prints out those cards and they are sent through the mail to that library so they can save the money required to make their own catalogue cards. Also the computer is developing a central catalogue of all books held in all participating libraries and eventually it will keep a record of all books that are in the libraries and those which are circulating so that if any other library wishes to borrow one, it can quickly identify the nearest library which has a copy of the desired book. These steps are being taken to expand this system throughout the country through the Inter-University Communication Council (EDUCOM).

Numerous audio and video cassette courses are now available and can be sent by mail anywhere in the world.

International University. Plans are under way to establish an international university so that a student in any country can receive instructional materials to take courses in other colleges and-universities throughout the world. The International University arranges for him to receive these materials, provides counseling in his home country concerning its own educational progress, and also provides examinations which he can take in his own language and in his own country. If he passes these examinations he can receive through the International University a degree from a foreign university of his choice without leaving his own country.

Experiments by Dr. Patrick Suppes at Stanford University are now underway using computer aided instruction for school children by satellite between Stanford University and Brazil. Students in Brazil can use computer terminals and over the satellite can interact with the computer which is located in Stanford, California.

Experiments are also underway for providing the highly repetitive instruction necessary to permit feebleminded children to learn. This can in many ways be done better by computers than human beings, because computers do not tire with many repetitions as human instructors do, even though those instructors are very sympathetic to the problems and needs of their feebleminded students.

APPROACHES TO USE OF TECHNOLOGY FOR SPECIFIC DIFFICULT PROBLEMS SUCH AS MEDICAL EDUCATION*

Teachers now seem to be able to work more and more with instructional technology. They are making their classrooms into more open systems rather than the closed system of the past in which the teacher knew all and dispensed all.

In the current more-open system, teachers must learn to develop a degree of emotional stability and internal security that is often not needed in the more-traditional situation. One of the reasons that teachers become authoritarian in closed systems is because they are aware of their own limitations in knowledge. They naturally tend to stop conversations or prevent discussions in the classroom from going beyond the limits of what they already know, fearing being shown up as ignorant.

One of the most interesting results of the English Language Television project in El Salvador was the impact that it had upon teacher behavior. The teachers were aware that they themselves did not speak English as well as did the teacher on television, and they thus accepted the fact that they themselves were not accurate all the time. There was someone on TV who knew more about this particular subject than they did. One of the teachers in El Salvador said to me that if this phenomenon is true in English, think of the problems I have teaching 9th Grade Science. His 9th Grade Science even included References to Nuclear Physics, and as he said, "I just don't know enough in this area of science."

What teachers are forced to do in a situation such as this, therefore, is to develop a sense of humility that has not been traditional among teachers. Along with this humility must come an ability to manage information as part of the system rather than to dictate the information and to declare in an absolute sense what is right and wrong. Thus, one of the most fundamental shifts that is necessary among teachers when employing modern instructional technology is an emotional adjustment in addition to intellectual adjustment. It is a form of maturity when a teacher can achieve such an adjustment, and it is a great advance for the educational process if he can do so.

* Reproduced from the recorded tapes with slight editing by the INNOTECH staff.

The traditional teacher's absolute sense of what is right and wrong can be illustrated by a personal and very dramatic experience of my own life. When I was in medical school, I was visiting in a foreign country where they had a highly didactic form of teaching. I was visiting with a physician who had a group of students who were working with him on a clinical case of a patient that had died of chest disease. The diagnosis before death was that the patient had tuberculosis. During the autopsy the pathologist was looking at the lungs, and the moment he brought out the lungs, it was obvious that is was cancer of the lungs, not tuberculosis. He, being a junior rather than a senior pathologist and knowing that the diagnosis of death had been tuberculosis, said nothing. He simply exposed the lungs for examination, and at that moment as the clinician was explaining that this was obviously a case of tuberculosis, the Senior Pathologist came in. The senior man was with his students, and without knowing what had been said by the junior pathologist, indicated to his students that this was an obvious case of cancer. It was clear to all of us who were there that it was a very difficult and emotional time for the clinical professor to accept the situation.

I would like to switch now in my talk and explore some of the more complex applications of instructional technology and to introduce them by looking at what I am calling the "Total Society". There are a number of sub-systems within a society or a nation. First of all, there is a "Reproducer Sub-system". To reproduce means to charter or to begin a new form of a component of a society, a new organisational system which is different from the one that went before. I think INNOTECH, itself, is an example of an organisation which has devoted itself toward the reproduction of a new educational system. The idea of reproduction as a social system is not the same as biological reproduction; social systems do not reproduce biologically, the component individuals do. Social systems reproduce by new charges, such as new constitutions, and they also reproduce by persons acting as change agents, much as can happen as persons go from INNOTECH as change agents back to their own countries.

There is also what I am calling a "Boundary Sub-system". We have talked earlier about the difficulty of having information cross over boundaries, such as the difficulty of having one teacher learn from another teacher. If a teacher is in a traditional closed classroom in which he is the "authority", then it is difficult for another teacher to appear to criticise him because he is in no position to receive such criticism. The same thing is true from one school to another or from one nation to another. For example, in El Salvador there are no diplomatic relations with their next door neighbour, Honduras. A Mexican can travel through both countries by the

Inter-American Highway, but no one in El Salvador can go through the Hondurian part and no one from Honduras can go through that part of the Inter-American Highway which traverses El Salvador. Think then how difficult it might be for the transfer of educational change from one of these countries to another.

Another noticeable boundary is the "Language boundary". It is true that national boundaries often correspond to language boundaries, particularly in South East Asia. Language differences are profound boundaries, and we have two choices to diminish the strain of such boundaries. One choice is to find some international language and the other is to translate. Translation, by itself, means using the decoder sub-system at this language boundary in such a way that the boundary can be breached. One example would be the translation of Sesame Street from American English to the language of a Southeast Asian country.

Another important sub-system is the "Distributor Sub-system". Referring to El Salvador again, we found that one of the reasons why the programme in that country worked so well was because the roads were good and because the road distances were relatively short. Among other things, this efficient distributor sub-system meant that it would be easier to repair television sets when they broke down because they could be taken quite simply to a central location. If the distributor sub-system were such as existing in Brazil or India with their difficult transportation problems, the maintenance of any form of electronic equipment would become much more difficult.

El Salvador also has electricity in every part of the country, and costs can be held down, and there is no need to consider the use of battery-operated sets. In Brazil, on the other hand, the plans from the beginning have been to provide television sets that will be battery operated. There is a need for electricity, however, and there will be a problem in distribution in installing the generators, in providing fuel for them and in providing channels for the distribution of electricity.

Another sub-system is called the "Supporter Sub-system". The relevant question concerning the Supporter Sub-system is whether there is a need for large skeletons of schools, much brick, and money for buildings for educational systems -- or whether it is more important to concentrate your money on what is the essence: the information processing sub-system. I personally think that a careful look should be given to emphasizing the information processing sub-system over what I am calling the skeleton of the educational system, i.e., buildings, etc. One difficulty on doing so is in overcoming the traditional skeleton that is wanted by the traditionalists and the old men who want their memories continued to represent what is sometimes referred to as "tombstone complex". They want something with their name on it to represent them, and they thus favour buildings, especially if those buildings will someday be named after them -- and the sooner the better. It is this background to some extent that promotes the conviction that a building must come first before education can start. I don't doubt that there are many such situations, particularly in cold climates, where this is utterly essential, but it would be a mistake to spend a great deal of money on the relatively and unimportant support sub-system and neglecting the essential information processing sub-systems.

One of the important components of the information processing sub-system is the "Input Transducer" that brings information into the system. There are closed classrooms, closed nations and closed input transducers. One example of such a closed input transducer comes from a discussion I had with a friend of mine who is a professor at a French University. He asked me one day: "Do you know that there are only two Professors in France who are not born in France? I am one, and I was born only three miles inside Switzerland from the French Border." I agree that the French are a brilliant nation, but are there no other ideas that are worth teaching in France except French ideas? The French are not alone. The notion of being open to textbooks from abroad and to instruction of all sorts from abroad is one that is quite new in many countries. The new instructional technologies will very rapidly accelerate the introduction of ideas of one country to another, especially if we are to start having things like satellites which bring instructional materials across national borders.

The "Internal Transducer" is something like an organ of a human body that transmits information from inside the system. Does an educational system have feedback from the students themselves, or from the parents or from the others who care about the future and about what students learn and whether they are satisfied with their learning experiences. This form of internal feedback is extremely important for the development of a healthy national educational system.

Most of our discussion actually has dealt with the Channel-and-net Sub-system. The earliest example of such a sub-system is the spread of information by word of mouth from one person to another. This spread was limited by the rate with which a human being can move around and by the effectiveness of the mail or other means of information dissemination. Later, of course, there has been the spread of information by books and journals and magazines and newspapers and so on. But there are other ways that now operate as channels and nets. For example, it is now possible in any country in the world to send or receive cassettes which can be recorded or played any place. This is an electronic channel and also a net of a sort. There is also radio and television, and there are satellites. The question that should be asked is whether these channels are any better than those used previously. In other words, are they faster in a way that is important? Does the audio or visual of television give you better education than the audio alone? Are the satellites going to be more useful? Another question: Are such sub-systems better, are they worth the tremendous cost?

There are other questions worth asking about channels and nets. For example, one of the arguments being used in Brazil in favour of the satellite is that it eliminates the need for cables or even microwaves for television in the Amazon jungle. Again, in other parts of the world, where there are several disruptions occasionally and where there are robbers and various forms of violence that cannot be wholly controlled by the authorities, the satellite would avoid interruptions from these sources. The base problem disappears when you use the satellite.

The "Dispersed Sub-system" is where learning goes on in a society. Learning goes on in each individual component. Even though learning goes on in integrated groups to some degree, in the sense that one goes to school where all are learning together, learning still is an individual matter of the individual component. And this is the essence of what we are talking about in education. It is also here that many questions come up. These questions concern innovations and curriculum, the number of times that something should be repeated for it to be remembered best, the form of presentation and whether it should be both visual and auditory in order to be remembered best, the part of active participation of students in order to learn best, the many forms of organisation and alternative content that would be most effective, etc.

The society memory represents not only the memories stored in each individual but also common memories like libraries and so on. Libraries which are utterly unavailable in many parts of the world could easily be made available through international communications. Already experiments are being done from the National Library in Washington over satellites, to other countries, particularly in South America. The abstracts of general articles, scientific articles in the field of biology and medicine which are stored in computers in the national library of medicine in Washington, can be obtained over satellite at a terminal located in another country.

You will simply type in a list of terms, called the medical standard terminology. Xerox copies of the articles you need will then be sent to you by airmail. Now this access to the memory of the world, you might say, to the memory of the society, is a thing that must be considered as a real potential in the very near future and is a fundamental part of the total process of education in the society.

Finally, there is the output transducer sub-system. This deals with what one nation does for another nation, and the question of whether or not there should be international plans for education that would share these resources across national borders. They can be shared by satellite, by television cables, by sending video cassettes or audio cassettes around the world. There are many ways in which this can be done.

Let me give an example. One of the things I was to speak about concerns the applications of technologies in the field of medical education. There are a number of these now. For instance, it is now possible for a ship at sea with no doctor on it, to broadcast to a satellite and have a doctor examine the patient on the ship. Television cameras show the patient's tongue, or chest, or broken arm. The doctor gives his diagnose and treats the patient over the satellite. It is even possible for a doctor to listen to the heart over a stethoscope, or to have an electric cardiograph. These things are being experimented now.

Another thing is to have a patient sit down and answer questions on a television, like "Do you have a cough?" "No". "Do you have a temperature?" "Yes", and so on. He then gets a blood test and a urine test done by automated equipment, and then it goes to a computer, all of it automatically. The doctor gets a summary of it plus the computer's suggestions in order of probability of what the diagnoses are, and then the doctor sees the patient for the first time.

Part of education in medicine today is learning to live with a computer. This is not only for the physicians, but for the live healthy personnel as well. The Department of Health Education and Welfare gave about half a million dollars for the development of the Ohio State Medical School of what is known as the Pilot Medical School programme. This is fundamentally computer-aided instruction. It operates 22 hours a day and the students can come in and study when he wants to, at his own rate. He continues recording his answers and responses by typing them in, and so actually no examinations are needed. After all, examinations are simply samples of your total knowledge, but this computer knows everything that every student has learned, and it can point out reports for the teacher about the student, what percentage of his answers is correct and how he is progressing.

Undoubtedly, there are a lot of problems, but this is an example of how it has been possible in a modern medical school to put a very complex advanced field on the computer. The entire programme is on a disc pack, that is about 12 large phonograph records which are all put in a big plastic holder and you can carry it by a handle. It weighs about 40 pounds. The AED plans to have it translated into Spanish. Once it is translated (this will cost probably half a million American dollars), a disc pack would cost only a thousand or two thousand dollars. And then instead of having rather poor basic medical science training, which is the case in many of the Latin American nations, you have quite an advanced, modern training available in the language of the individuals who want it.

Another example is the use of television. An extensive programme is going on at the University of Illinois. Urbana, Illinois, which is the main campus of the University of Illinois, is 110 miles away from another campus of the same university, the Chicago Circle Campus. The two campuses are connected by a television link. I heard that last year 30 complete courses were given by the faculty at Urbana. The teaching was done at Urbana and picked up by television. The students take them in classrooms at Chicago. This is a large programme of the application of educational television in a large university for advanced instruction. This university has also Programme PLATO which is even more complicated. The television screen is different from the ordinary one. It is a very thin waver, actually a piece of plastic about less than an inch thick, about 11 by 11 inches. It stands in a little frame, almost like a mirror and it has wires coming into it from the computer. It can produce in colour pictures, animated pictures controlled by the computer coming from the television tape. It can also produce pictures, drawn, or letters drawn by the computer on the screen. The number of lines is 1100 which is much finer, giving a much sharper picture than you would get in an American TV. The student can sit at the type-writer and the responses of the computer in either still or moving pictures in black and white or in colour, can appear on the screen. At present 200 courses are being given in this way at Urbana. Obviously once the information is stored, it will be relatively cheap to send it over wires to nearly all universities, like the University of Indiana.

It is interesting to know that the Ohio State Medical programme has been used for one year by the University of Virginia, and for next year the University of Wisconsin Medical School has asked for eleven or twelve terminals. This is a way of spreading a T.V. programme from one place to another across boundaries.

I have a book called "Eduned" that I wrote in 1966 together with two others, as a result of a federally sponsored programme to plan a national educational network to inter-connect the colleges and the universities in the country, and I will leave this book to INNOTECH. This programme was fundamentally meant to create a medium network throughout the whole country by micro-wave length. But it was not done yet.

A related idea is the Ohio College Library Council system. This is a system from Columbus, Ohio. It is operating in the following way: each library that participates has a television and a typewriter, a terminal of this sort, and when they get a new book they type in the name of the author and the book, and that goes to the computer in Columbus, Ohio, and the computer sends back a message which is put on the screen. It says "we do not have the book in our computer memory", or "here is the catalogue card", and if you want it, you push the key "y", which means "yes". You then get a complete set of catalogue cards, all typed out the way your library does it. Plans are also underway to have a system whereby a person who wants a book will know that the book is out, and when it will be back. And when another library wants a book they will type in the name of the author and the name of the book and the computer will find in which of the 70 libraries the book is and send a message to them asking them to send the book by mail to another library. This programme is being extended by an organisation called Educom and it is a programme which could operate perfectly well over the satellite on an international basis because nothing is needed in addition to an ordinary telephone line.

Another plan is to develop an International University with all levels of instruction, beginning with the lowest grade in pre-collegiate and collegiate levels to the graduate level and the professional level with the hope that these media can be exchanged from one part of the world to another. And that someone from your country, for example, who might want to study as the participant at the University of Tokyo, at the University of Cincinati or the Sorbonne, or wherever, could go to a local office of the international universities and could take examinations in order to find what level he was at and then decide with a councellor there, that he was qualified to take a certain course in one of these other universities. He could then enrol through the

International University and he could receive syllabuses and course materials, textbooks, cassettes, video tapes, even satellites instruction perhaps, at home and study that way. When he was ready, he could come back to the Center and take an examination written by the university where he was studying, and if he passed the examination he would receive a degree from that university at home with the seal of that university and underneath the seal of the International University. Now this is a dream that some of us have. But the Technology is available and it is an extreme example of how we might some day before too long be able to share our resources.

Well, these are a few of the more difficult and more complex and advance applications. Some of them are going on now, some of them are just dreams, but technically all of them are possible.

APPENDIX

THE AGENCY FOR INTERNATIONAL DEVELOPMENT
AND
EDUCATIONAL TECHNOLOGY IN THE DEVELOPING COUNTRIES

by Clifford H. Block

PREFACE

The purpose of this paper -- which was originally presented to attendees at an Agency for International Development international seminar on educational technology in November of 1971 -- is to examine educational technology, its current applications, and its potential for improving education in the developing countries.

The ideas in this paper do not represent a "policy" of AID. Indeed, the only stated policy of AID in this area is one of assisting the developing countries in "exploring the potential" of the educational and communications technologies for development. The means of such assistance can take many forms, all appropriate to particular situations. We do, however, as most large institutions, agree on a wide array of working assumptions which shape many of our activities in this field.

An overriding purpose of this paper, therefore, is to share our assumptions and our limited knowledge and experience, to identify some of the problems and issues which we believe to be important, and to seek counsel and the continuing association of experts and practitioners in utilizing educational technology as a major instrument of social and economic advancement.

In our discussion we will include two elements when we use the term "educational technology":

Devices for delivering informational and educational materials -- we speak, particularly of the newer electronic media of television, films, radio, computers, and others, together with the older technologies such as textbooks.

A set of methodologies for organizing the content of the educational process. By this we mean "a systematic way of designing, carrying out, and evaluating the total process of learning and teaching in terms of specific objectives, based on research in human learning and communication, and employing a combination of human and nonhuman resources to bring about more effective instruction." 1/

In developing country applications, both of these elements are ...al. A fundamental and universal challenge is that of delivering ...rning opportunities to more people with less dependence on direct contact with highly trained purveyors to information -- teachers, extension workers, and trainers. The sheer lack of adequate numbers of such people in the near future, the long time required to prepare skilled teachers or trainers, and the prohibitively high cost of paying for adequate numbers of such teachers and trainers makes this search for new delivery methods almost mandatory.

In addition, it is our conviction that present instructional methods are inadequate, that the cost effectiveness of traditional education is extremely low, and that mass education of high quality, can be achieved only through the use of learning methodologies more effectively than those in common use today.

Clifford H. Block
Office of Education and Human Resources
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1/ Report, Commission on Instructional Technology, Committee on Education and Labor, House, GPO, Washington, March, 1970. Page 5

I. Applications of Educational and Communications Technologies in Developing Countries

The potential applications of educational and communications technologies are almost limitless and encompass almost all of the areas where human learning (of skills, of information, and of attitudes) is important. These media systems can be used for everything from the upgrading of the specialized training of physicians, scholars or industrial managers to the providing of basic education and information to the nonliterate rural families of the world.

Although the potential applications in lesser developed country situations are almost limitless, resources are not. Development assistance agencies must select a few important areas where their limited professional and financial resources can be efficiently concentrated so that they have the best effect. Obviously, the selection of such priority areas must accord with, and largely be generated by, the overall objectives of the developing nations who utilize these newer technologies.

The Agency for International Development is primarily concentrating its activities in educational technology on two major areas: (1) the expansion and improvement of formal schooling, particularly that offered in grades one through nine; and (2) the development of nonformal (out of school) programs of information and basic education that are more accessible to rural families and the urban poor.

The populations represented in these two areas are of crucial importance to social, economic, and political development. At the same time, progress in both areas is now critically impeded either by the inadequacy of present systems -- lack of qualified teachers, suitable curriculum, materials, and methodology -- or by the total absence of such systems.

<u>For education offered within schools, the potential of educational technology rests in achieving systems which</u>:

- Guarantee lower unit costs than conventional systems.
- Encourage efficiency in learning, resulting in faster average progression through the school system.
- Reduce requirements for trained teachers and administrators.
- Deliver education to a greater number of learners.

- Achieve more relevant educational experience both for the individual and for the good of national development.

- Build into the educational system some mechanisms for continuing improvement, by relating educational practices more closely to learning effectiveness.

- Effect educational change far more rapidly than is possible through conventional systems.

<u>In effecting learning outside of schools, the communications technologies are perhaps even more impressive in their potential ability to generate programs which:</u>

- Reach nonliterate or semiliterate populations with useful information and education.

- Enable key institutions in a country to communicate directly with the majority of the population and thereby increase the effectiveness of many kinds of development programs.

- Enable people in one part of a country to learn about other segments of their nation and to encourage a greater sense of national identity.

- Extend the effective reach of development field agents in agriculture, family planning, health, and other areas.

- Provide governments with a means to receive more useful feedback on their programs from the population that they serve.

- Facilitate administration of virtually every development sector within a country.

- Accelerate, through the availability of a mass of information, the modernization process in rural and otherwise isolated communities.

II. <u>The State of the Art</u>

An assessment of activities aimed at achieving these goals in both in-school and out-of-school situations must start with a review of the current state of the art, which is best explained in a discussion of research and experimental and operational projects.

Research

Fundamental research could well produce breakthroughs in education during the next decade, but it would be pure folly to attempt to predict exactly what such developments will be and when they will occur. Among the many fields where such breakthroughs could occur are the study of: cognitive styles; the conditions of learning and problem solving (both enviromental and physiological); intellectual development in early childhood; bio-feedback effects on individual, intellectual and emotional control; attitude formation; the extension of behavioral studies on the conditions of reinforcement; and several areas of brain research.

It is likely that new knowledge from one or more of these fields will revolutionize educational practice in the near future. However, the implications for policy are not precise because current systems cannot be designed to accommodate as yet unmade discoveries. We can, however, strive to ensure that systems remain open to experimentation with radically new practices. In that way, the next waves of innovation will encounter less institutional resistance than is the case at present.

There is a vast body of on-going applied research, primarily from the industrialized countries, which is applicable in such areas as media effectiveness, feedback systems, methods for individualizing instructional pace and content, ways of defining objectives behaviorally, and many other elements involved in the choosing and designing of an instructional technology system. Those studies dealing with the media are summarized in the many works of Wilbur Schramm and his colleagues, particularly in his study, in collaboration with Chu, Learning from Television: What the Research Says, which summarizes the key generalizations on the use of the media in education from several hundred studies.

Another stream of applied reserch of high significance is associated with programmed instruction and its descendants, computer-assisted and computer-managed instruction. The application of principles of learning to educational practice in this research is of profound importance. Although we would not endeavor to summarize such findings, we do believe that a working knowledge of how to precisely control the conditions of learning, in order to achieve a maximum rate of individual growth, is proceeding rapidly. The conditions of stimulus presentation, reinforcement, feedback, and practice, are all now better understood. In fact, many of these techniques have been developed in operational form and used for training purposes.

Finally, applied research in adapting systems analysis to education may have a major future payoff. In our view, the formal techniques of this methodology still require modification to fit the complex, difficult-to-quantify, aspects of education. However, even now the basic systems approach is useful in analyzing problems and the different functions of educational systems, investigating alternative solutions, and deriving systems which take into account inputs, interactions among system components, and outputs.

From this great array of research on learning processes and on media effects, two fundamental conclusions stand out:

- We can teach almost anyone effectively -- by television or by other media -- if content is appropriately programmed in relation to individual abilities and motivations.
- There are a substantial number of specific principles and methodologies which can serve as guides for such effective programming, whether by mass media, individual media, or combination thereof.

In short. even though there are obvious differences among the media, we can use virtually all of them effectively in instruction.

The next question, then, for our purpose, is whether or not reasonable effectiveness can be achieved in actual systems -- in situations where educators are forced to cope with problems of delivering a whole series of learning experience to a wide range of learners under less than optimal conditions.

Experimental and Operational Projects

The translation of research findings and innovative ideas into actual practice is, of course, the key step in tapping the potential of educational technology. And AID has been a major catalyst in the evaluation of many of these experiments.

A number of key experimental and operational projects all over the world influence our thinking about the practical potential of various technological approaches. In brief, such projects indicate the following about the current state of affairs:

For Within-School Education

Several projects are showing that, when television is used intensively as part of an integrated new system of educational inputs, change and improvement can be implemented quickly as in El Salvador and Niger, particularly. We do not yet know the extent of improvement in learning effectiveness. However, it appears to be very substantial. Earlier field trials had demonstrated the ineffectiveness of small-scale additive uses of educational technologies; being designed to make little difference, they, in fact, do not affect learning in any great way. Further, they do not stimulate the changes in basic teacher and student behavior that are essential for improving education significantly.

Implementation of an intensive, integrated model has only occurred on a small scale to date (30,000 students in El Salvador). However, one such system has just begun in the Ivory Coast on a larger scale — 15,000 first grade students in the first year -- and will ultimately encompass several hundred thousand students. This experiment is aimed at major reduction in the unit cost of education by reducing the repeater and drop-out rates.

These new systems are the precursors of other efforts to use a variety of instructional technologies in integrated, new, learning systems that are carefully designed to achieve reforms, efficiencies, and cost reductions and, in some cases, to expand educational opportunities significantly (particularly in Korea and Brazil, among others).

One major research and development effort is beginning in India which utilizes a very low-cost technology, programmed instruction, for upgrading primary schools. At the other end of the cost spectrum, computer-aided instruction is being used for teacher upgrading in Spain.

For Out-of-School Education and Information

The experience in the use of the educational technologies for nonformal education and social development is slight, except for radio literacy programs and quite specialized uses in family planning, agriculture, etc. (India's Radio Rural Forum for example). At least two major projects are being planned, however, both aimed at using the instructional technologies to make a significant difference in the lives of village people. (India's satellite experiment; Guatemala).

On the basis of current evidence and experience, we are encouraged in our basic operating assumption that educational systems, utilizing the newer communications media and the concepts of instructional technology, can be developed which will have very significant advantages over present educational and human resource development systems. We assume, furthermore, that the establishment of such systems will initiate a process of continuing innovation, based on a linkage between educational practice and the scientific study of the effects of such practice on learning and behavior.

If our assumptions are tenable, the use of the educational technologies holds promise for alleviating some of the problems of development -- the lack of educational opportunity and access to useful information for most people, the great inefficiency and irrelevance of much of the education that does exist, and the prohibitively high unit cost of all educational systems.

III. Strategic Directions

At this point, however, there are no operational systems of sufficiently broad scope and low enough cost to serve as models for developing countries. We are thus engaged in searching for a strategy which will lead to the expeditious development of such systems with wide and reliable applicability to the problems faced by many developing countries. This search is at different stages for both in-school and out-of-school learning systems.

In-School Applications

There seems to be a general strategy for effective in-school applications of the educational technologies -- namely, to use their introduction as a catalyst for achieving broad, systematic changes in the content, organization, methods, and results of education and to use them as core instruments for delivering a major, integrated part of the instructional load. However, we are still at an early stage of practical experience with such systems, and major barriers must still be overcome if the promised potentials are to be attained. Among the key barriers are the following:

- Inadequate experience with planning and administering large systems.

- Inadequate experience in designing systems aimed at reducing cost (by using less-trained teachers, increasing the number of students reached by one teacher, or increasing the rate of student progress through the system).

- Inadequate methodologies for producing really effective instructional radio or television programs for use.

- Too little experience with tailoring educational content to differences among groups, regions, and individuals.

- Too few trained planners, both in the developing world and elsewhere, who are largely scattered and apart from an adequate institutional base.

- Problems of electrical power, reliability, and cost of electronic components.

- Reluctance on the part of many countries to adopt the wholesale changes required to make new educational systems most productive.

Among the key activities of any program that is designed to overcome these and related barriers are the following:

- New ideas must be produced -- for new kinds of systems and/or ways to make the components of current systems work better. Such ideas can come from experimental research, from evaluating the way things are done in various countries, from systematic analysis, and (perhaps most productively) from the insights of individual creative people.

- Key ideas must be communicated among those who make decisions that affect educational programs. Today, the discredited supplementary approaches to instructional media are still practiced; hardware is still acquired before its use is understood.

- Plans that incorporate the best of the new ideas must then be developed to solve specific problems in specific countries.

- Plans must be tested in the developing countries -- in pilot projects and in research and development efforts.

- Careful evaluations must be made of the costs, effects, and operational feasibility of these trials.

- Full-scale operational projects must be undertaken to put the whole process to its final test. This will demand commitment from the highest levels of each developing nation.

The above process need not be sequential. Indeed, whether or not it should follow this sequence is one of the first strategic choices to be considered. Most scientific researchers and rational planners believe that the process should follow approximately the sequence outlined above — essentially, research and analysis, experimentation, small-scale trials, a pilot project, evaluation, and, only then, implementation through a large-scale operating system.

Another school of thought holds that an effective administrator should be given the power and resources to put a system into operation (with the implied high level of national commitment required to do so) and that a system should become operational as quickly as possible, with "fine-tuning" improvements left as a second stage. The contrast with the prior strategy presents perhaps the most fundamental strategic choice that a nation interested in utilizing educational technology must face.

AID is currently supporting both of these approaches — the former in Korea and the latter in El Salvador. The common principle of both is that high commitment must be obtained if either approach is to achieve its desired ends. In the more "scientific" development option, commitment to use the end result for an operational program must be maintained over a long period and, if the R&D is to be adequate, must be supported throughout by substantial funding — i.e., the development period cannot be viewed as an alternative to decision, but rather as a step in implementing a decision to create a major operational system, if the development succeeds.

The alternative approach, of course, has the risk of creating an inadequate system into which a country may be locked because of the heavy investment required. To date, however, it is this approach which has been instrumental to progress in this field.

No matter the approach, we reiterate our conviction that further progress within schools is basically dependent on an increase in the number of pilot and/or operational systems designed to achieve the major changes in education that were discussed earlier. Such actual operating projects are essential both for learning how to effectively create such systems and for serving as models for other countries.

Out-of-School Applications.

There is the hope that, just as the systematic and intensive use of the instructional technologies for reform may produce breakthroughs in formal education, new applications in the use of communications for other development purposes will yield high payoff. However, these new strategies have yet to be developed and tested.

Almost everyone recognizes the fundamental role that communications play in creating a climate for change, in providing new ideas, and in producing some of the information needed to effect changes in all communities. On the other hand, the use of communications has been sporadic, largely uninformed by analyses of effectiveness, unintegrated with development efforts, and without a strategy. It is our assumption that, as in formal education, these methods can serve both as a catalyst for basic change and as an instrument for affecting some of those changes. Yet, at this point in time, we have only very general notions about how that might come about.

At this stage, the most significant barriers to progress are very general and fundamental:

- Our concepts are not fully formulated or tested;
- Few countries feel they can commit sufficient resources needed to test new approaches for mass education and information outside of the formal school.

There are only a few examples of programs where modern communications are used to make a real difference in current social development. This area will therefore require a great deal of new invention. The implementation of these inventions will, at first, appear to be high risk in character. However, the potential and probable pay offs are so great that we believe such risks can legitimately be undertaken.

As a first effort, we are exploring the implications of a somewhat different concept of the use of these technologies in education, namely to develop the broad goal of increasing "access to information" rather than of simply providing education. Such a concept, of course, implies both development of the skills needed to seek out relevant information and the continuing availability of a bank of information at the local level. The basic end result of activities in these fields is to test prototype systems which provide their target audience with the information they need at a time they need it, at reasonable cost, and at a place convenient to them.

In order to do this, prototype systems must be created over the next few years. In many cases, these systems will be new in conception. Among the questions guiding the design of those projects will be the following:

- Can programming be integrated among development activities, so that messages in agricultural practice reinforce those in nutrition, basic education, etc.

- Can the behavioral definition of objectives, so much at the core of individualized systems of educational technology, yield similar gains in these other areas?

- Can the illiteracy barrier be leaped?

- What should the messages be? We know very little about what information can be valuable to large developing country populations and even less about how to effectively communicate that information.

- How can learning be facilitated with a minimum of local interpersonal assistance? In most countries, it is simply not feasible to have a large structure of local monitors, even though communications theorists constantly cite their value. Much of the job will have to be done without the kind of organization and training that a system of local monitors would require. New methods must be developed for fulfilling the functions of such monitors, such as stimulating discussion of what has been learned, providing feedback to the producers of programs and ensuring organization at the point of reception.

- Where local monitors or development workers do exist, how can they be provided with the tools needed to enhance their work and increase their reach?

- To what degree can personnel and facilities of existing schools be used to affect cost savings?

In summary, the potentials of educational technology have not yet been at all demonstrated for out-of-school applications. Conceptually and logically, they hold equal or greater promise for the many learning requirements outside of school than for those within formal schools. However, sensible, sustained experimentation, research, and evaluation will be required to produce models which demonstrate that this potential can, in fact, be achieved. For most developing countries, however, the basic motivation for such continuing effort is that there is no available alternative.

IV. The Future of Educational Technology in the Developing Countries

The foregoing pages have suggested that use of the newer educational media offers the best potential for quantitative expansion and qualitative improvement of education, at acceptable cost, among the options now available. However, there are many difficult problems that must be overcome if these potentials are to be realized.

Consequently, there are certain fundamental issues confronting both developing countries and development assistance agencies. These include:

- The kinds of policy and resource commitments the developing countries are prepared to make.
- The kinds of policy and resource commitments the development assistance agencies are prepared to make.
- The overall array of activities required over the next few years to realize the potentials of educational technology.
- The special educational problems, interests, resources, and objectives of each developing country.
- The special interests, resources, and competence of each development assistance agency.
- Effective ways and means of coordinating the joint efforts of developing countries and development assistance agencies in research, development, experimentation, and applications of educational technology.

The realization of the potential of educational technology will require the combined resources of the developing countries and development assistance agencies for at least another decade. Unless this is done, education in developing countries will probably be worse ten years from now than it is today.

AID Activities

Within this contract, we will now discuss some of the more important activities in which AID is now involved and which we expect to engage in the future, subject to review.

Project Planning Assistance

Less developed countries continue to need expert assistance in planning projects. We do not necessarily mean "educational planning" which involves large allocation of resources. Instead, we refer to the planning necessary to decide the kind of system a country could reasonably accept and how to go about implementing such a system.

Project planning is an area in which no country, including the United States, can claim any large measure of competence at present. Such experience can only be acquired and applied by learning from activities in cooperation with the developing countries and other development assistance agencies.

We propose to help provide the best talent available to developing nations, explore ways to further increase the numbers of people with such skills, and to work toward creating more institutional centers to foster such expertise. Substantively, we will continue to emphasize the importance of those individuals sophisticated in the methodological aspects of instructional technology, rather than those well-versed in the hardware aspects. We have and will continue to assemble planning teams which combine such competencies as educational technology planning, instructional systems design, economics, systems analysis, teacher training, and instructional media knowledge. Accordingly, we no longer entrust initial planning to "television teams," "programmed instruction teams," etc.

Given the above, we nonetheless are willing to concede that unbiased, objective evaluation of alternative systems rarely seems possible. The development of formal planning methodologies that clearly relate the special needs of developing countries to a wide range of options would represent a major breakthrough.

Information Development and Dissemination

AID will continue to place a high priority on providing information to developing country planners that facilitates their use of instructional technologies. Thus, the AID-funded program which has produced a film and handbook on educational technology and an information and reference center, both at the Academy for Educational Development, will be continued at least through mid-1973. The further continuance of this activity will depend on the support of other sponsors and users. Meanwhile, the information needs of the developing countries will be further assessed. A series of seminars centering on the film and handbook will occur throughout the developing world over the next eighteen months and will assist us in this definition of needs.

Networks of available information should be created. The sharing of information among developing countries working with similar systems may be the most important link in such a network. We hope over the next year to develop a plan, in cooperation with the United Nations, other multilateral agencies, and other bilateral donors, to facilitate the establishment of this kind of network.

Institutional Development

AID has attempted to increase the potential of U.S. institutions to assist the developing countries in the educational technology field. A recent $1 million grant to Florida State University is the most significant effort to date and provides the F.S.U. Center for Educational Technology with a greater perspective in its work with developing countries. A similar 1970 grant, to U.C.L.A., provides resources for examining innovation in Latin American education, including the use of instructional technologies. Finally, the array of study contracts in this and related fields have provided for significantly greater institutional capacities at the Academy for Educational Development, Stanford University (in the area of non-formal education), and, to a lesser extent, at several other institutions. For instance, in the field of population communications, the East-West Center is rapidly becoming a major resource as a result of AID funding.

In spite of these efforts, the institutional framework for professional activity is still grossly inadequate. We can identify three areas where we would hope, by working with other assistance agencies, to strengthen the institutional base over the next five years: First, there is a need for a center similar to that at Florida State but with a greater focus on the use of mass communications and on communications theory. Second, there is a need for still another center which would concentrate on the practical problems associated with the production of educational materials for the new media; i.e., the production of quality institutional television programs, the strengthening of the institutional power of radio, and the development of mechanisms for making programmed instruction more effective for application in developing country situations. Third, there is an urgent need for the creation of greater institutional capacities within the developing world. At this point in time, the small Center for Educational Innovation and Technology (sponsored by the Southeast Asia Ministers of Education Organization) and the O.A.S. Centers in Education broadcasting in Latin America are the only organized attempts to improve the institutional capacities within the developing countries for planning, research, and technical assistance in the educational technologies. While linkages between the various U.S. and European centers and developing country institutions in this field are conciously being sought, the time will soon come when mechanisms will have to exist that provide direct support to the developing country institutions.

We do not wish to encourage a proliferation of institutional capacities in this field until the need for such is more apparent. Our emphasis in this area is first, therefore, on the development of project plans, with institutional development occurring later in relation to specific projects, planned or underway. We hope thereby to increase the usefulness of institutions as they develop.

Evaluation

AID has historically placed heavy emphasis on the importance of evaluating key field projects in educational technology. Thus, we have made a major investment in supporting evaluation of the El Salvador project, one of the most comprehensive evaluation programs ever undertaken of an educational innovation. Earlier, we funded the four volume series of case studies of the new media in education conducted by the International Institute for Educational Planning and published by UNESCO. We feel that policy and practice in the use of educational technology should be guided by objective evaluation of the effects of those practices. Such an evaluation should attempt to maintain a focus on what and how efficiently the individual student is learning and, at the same time, what the costs of the system are and will be.

We will continue to make evaluation an integral part of every educational system which we support. We will also continue to assess the relative costs and effects of other systems when countries themselves wish to make such determinations. Stanford University, for example, with AID support has just begun a study that will encompass at least six national systems using the new media and will specially emphasize two factors: first, comparisons between systems utilizing different media for the same educational objectives; and second, evaluation of the utility of lower cost, lower complexity technologies such as radio.

The kind of evaluation just described is the global variety, focusing on overall educational effects, attitudes, costs, and other results of introducing an innovative system. Lately, we have become increasingly aware of the need for a more detailed kind of assessment of the educational effectiveness of particular elements of an educational system. For example, at one level, it would be important to ascertain the relative contribution to learning in a system by the classroom teacher, by the television or radio lesson, or by the printed materials. With such knowledge, investments of effort and resources in one or the other element could be made with some awareness of the effect.

At an even more specific level, it would be useful for operators of projects to be able to identify those elements in a television or radio program which were contributing to its effectiveness or lack of such. This degree of precision in feedback, however, is almost never experienced except perhaps in such well controlled projects as "Sesame Street."

On the whole, it does not appear that there are adequate evaluative instruments available for making the kinds of discriminations that are needed in these kinds of detailed, feedback-related assessments. We hope to explore methods for improving these assessments more fully over the next several years.

Our evaluation program does not include detailed comparisons between one medium and another in delivering a certain kind of instruction to a particular audience. We are not yet convinced of the utility of the several hundred experiments of this sort, which have been conducted largely in the U.S. and Europe, mainly because of the basic inability to control the skill level of the producers of the various media that are being compared. Thus, a charismatic teacher on television may produce effective learning, while another teaching the same curriculum may be utterly ineffective. Therefore, comparisons between television teaching, for example, and programmed instruction are likely to be quite misleading unless repeated under a large number of conditions.

We also do not plan to launch major evaluative efforts of small supplementary uses of the media. Our present interest is only in uses of technology that are aimed at making a very major difference in educational effectiveness, cost, or relevance.

While our evaluation program has utilized terms such as "cost effectiveness," we are not yet sure how far such analyses can proceed. We do believe, however, that providing objective data on both costs and on educational effects to decision makers will enable them to make judgements about the utility of various kinds of systems. We anticipate that five years from now, when such data is available from El Salvador, the

Ivory Coast, Korea, India, Brazil, and a few other countries, we will be in a fairly strong position to suggest what kinds of educational effects and economies can be expected through current educational technology systems, given a certain level of investment.

Research

Apart from evaluation, we will support a related class or projects in experimental research. The overall aim of these projects is to develop new or improved ways of utilizing the instructional technologies for developing country purposes. These activities will range from quite specific research on a particular technique to small-scale pilot projects which will test out new systems. To date, there has been very little of such research directed toward educational technology systems appropriate to developing countries.

We believe increased investments in such applied research are likely to produce a high payoff and that increased investments are therefore worthwhile. At the same time, we are aware that the design of such projects has been inappropriately related to useful results for educational practitioners and that new approaches need to be developed. In a study just being completed (Academy for Educational Development, Abt Associates), we are attempting to define priority areas of research in this field. This project has thereby built on a number of prior contributions, including UNESCO's 1970 Volume on Educational Research Priorities. Accordingly, during the next six months, AID will circulate, throughout the professional community in the developing and developed world, a draft statement on research priorities based on the Abt study and other analyses.

AID's own funding for research of a generalizeable nature will continue to be severely limited. The role of other donor agencies will therefore be particularly critical in experimental research although there does not appear to be a surfeit of research funding available anywhere.

The most productive kinds of experimental research will probably be that closely related to a planned or ongoing operational project. Here, where immediate reliance of project payoff is apparent, funds are likely to be more readily available. For example, AID is supplying a certain percentage (usually 5 percent) of its sector loan funding in education for research and development activities, particularly in

Latin America. Brazil and Colombia have already received a substantial allotment of such funding and have committed themselves to match it with equal funding. They are also committed to developing a program for undertaking the appropriate research. In these countries, and in Korea and others where major commitments to develop alternative systems through educational technology will be made, major opportunities will surface for advancing the state of knowledge about and actual practice of effective application of educational technology systems.

There is no place where significant tryouts of new educational practices can occur on a fairly routine basis. This lack has retarded the development and improvement of such systems because it compels them to remain at a theoretical stage until some institution makes a commitment to actually use the technology. The equivalent of the agricultural "test bed" or "experimental farm" that Wilbur Schramm has so long urged upon education is still not available. We do not have a practical plan for establishing such a set of institutions. Perhaps this gap will catch the attention of a number of development assistance agencies and developing countries.

We do not have situations which permit ready establishment of pilot projects of a moderate scale. These are needed for the same reasons as the more limited "experimental farms" -- to try out new techniques that can be developed further.

What may be needed is a source of funding that clearly recognizes the high risk inherent in the first year or two of operation of a pilot project. At present, this represents a risk that most donor agencies cannot take nor recommend to recipient countries. Thus, those pilot projects, or first stages of operational projects, that are launched tend to be comparatively conservative adaptations of techniques in use elsewhere, rather than genuinely innovative systems.

The intellectual planning and the necessary hardware for more innovative systems do exist and are being further generated by new studies that we and others are undertaking. The basic lack of research surfaces in the nonexistence of an appropriate mechanism for funding a project that may fail because it is untried, but that, if it succeeds, may yield large benefits. If we assume success to be possible, we may attempt to develop mechanisms for supplying this kind of funding.

Studies of Strategies and New Options

Since July 1970, AID has sponsored a series of studies, under the overall direction of the Academy for Educational Development, aimed at analyzing some of the questions which underlie AID decisions on strategy and program policy in the educational technology field. By September 1973, most of these studies will be completed.

In brief, they include:

- An analysis of research priorities in educational technology (with Abt Associates).
- A review of policy issues surrounding the use of satellites for education and information in the developing countries.
- A study of the educational implications of choices among various kinds of national broadcast systems (e.g., satellite/microwave; television/radio, etc.)
- An analysis of the techno-economic implications of satellites and other kinds of national broadcast systems (by Massachusetts Institute of Technology).
- An analysis of activities that might be undertaken, prior to satellite deployment, as a country prepares for an educational satellite experiment or operating system.
- A series of studies aimed at suggesting new strategies for the effective use of communications for reaching the rural family and the urban poor in developing countries. This study focuses on methods for producing changes in maternal and child health care, nutritional practices, basic intellectual skills, family planning practices, and agricultural techniques (with George Washington University and others).

During 1972, as these studies near completion, our major concentration will be on transforming the ideas developed therein into a form likely to affect programs, practices, and policies. We are not yet certain how we will achieve this goal. A first step, however, will be to try out these ideas with those likely to use them -- developing-country professionals and decision-makers, as well as other experts from the developed world. Mechanisms for this dialogue will have to be developed.

We hope to bring together diverse groups of specialists -- social scientists, advertising men, creative broadcasters, educators, policy makers and others -- to work with these ideas in the hope that some operationally viable project plans will emerge.

We are already convinced that at least some of the strategic ideas which will emerge will be worth testing in pilot experiments or field projects. By mid-1972, therefore, we hope to begin planning some projects with a few developing countries that will carry into practice the most relevant of the ideas that have been produced.

In general, we think that our own resources for studies of the sort described in this section may in the future be used largely for helping field tests get underway. It may be, however, that follow-up or new studies will emerge during the next year with higher priorities than are now apparent. Subjects for such studies will be defined largely by the developing country users and partly by changes in the state-of-the-art.

Coordination of Agencies Concerned with Development

AID is prepared to cooperate fully in a systematic effort to coordinate research, planning, and action by the many developing countries and assistance agencies -- multilateral, bilateral, and national -- concerned with the applications of educational technology.

Of course, a considerable degree of inter-professional communication already exists, particularly encouraged when teams have come together to work on planning or evaluation projects. Undoubtedly, this will remain a highly useful form of coordination. However, a greater awareness of the strategies, plans, and projects of other agencies is also needed.

We are not now proposing that a formal mechanism or a detailed common strategy be developed among the various development assistance agencies. However, the greater impact on the state-of-the-art of such close coordination argues in its favor. On the other hand, some diversity of concepts, funding criteria, and objectives may in the long run be more useful.

Satellite Policy Studies

As yet, there have been no operating educational experiments with satellites. Many countries are exploring their potential, however. In addition to the aforementioned Indian experiment, the U.S. will utilize the same satellite in Alaska and in the Rocky Mountain States. In addition, serious planning is underway for possible in-school projects in Brazil and in a consortium of other Latin America countries.

The great potential of satellite broadcasting is of great interest to those countries or regional groupings of countries where population densities and geographic size may warrant its use. There is agreement that its major potential lies in the technology of the mid-1970's and later which will permit broadcasts to community and home television receivers with low cost augmentation and antenna equipment -- perhaps a total cost of as low as $200 per set required for the NASA ATS-F and ATS-6 series of experimental satellites by 1973 - 75.

With this "direct" broadcast potential, satellites offer several advantages: immediate potential coverage of very large areas -- one or more countries in many cases; the ability to reach economically remote mountain or jungle areas just as well as more developed areas: and the ability to reach, with relevant programs, specialized groups scattered over a whole country. Ultimately, the capacity to carry a large number of television channels as well as many radio frequencies may further add to the attractiveness of satellites to some countries.

We will not here deal with the many questions of satellite vs. microwave transmission, allocation of radio frequencies, legal agreements, et al, which make decisions in this area unusually complex. AID is preparing, under contract, a background study of some of these issues. That study will be circulated for general information by early 1972. However, at this juncture we might note that:

- AID is -- by Congressional directive and by long conviction -- dedicated to seeing that the social development applications of satellites for the developing nations are fully explored.
- We have taken the position in this, as in all of our educational technology efforts, that the matter of program content is one of [illegible]al national control and that project planning initiative and responsibility rests with the developing nations.
- We believe, with others, that successful use of educational

satellites for development will be a demanding task. All of the problems of conventional broadcasting remain -- producing effective programming that is integrated with other educational and information elements, providing feedback to keep programs meaningful, organizing and training utilization experts for classrooms or village groups, reducing receiver cost and maintenance, administering, large systems, maintenance and reliability of power sources and reception equipment, etc.

With satellites, however, some of these problems are compounded by size. In particular, the management of a centralized system involving many people spread over a large area will require new forms of educational administration. The heterogeneity of audiences will also demand either radically more creative programming which can leap cultural, national individual, and linguistic differences or, alternatively, methods for providing a sizeable proportion of more local programming.

These and other differences are probably surmountable. However, successful use of satellites will require a great innovative effort. It will take concentrated planning, research and development, creative programming, flexible experiments, and candid evaluation by those nations attempting to use these powerful systems.

Two other matters must be noted. First, the concern about reception of unwanted transmissions from one country to another is, as everyone recognizes, a matter of serious concern. Second, there has been too little analysis to date of methods of financing educational and social development broadcasting by combining costs with uses of other sectors -- telecommunications in particular.

AID's role to date has been limited to some studies, described elsewhere, designed to spell out the potentials, problems, and preparatory stages relating to satellite broadcasting for education. We have also participated with the U.S. Government policy bodies in this area. The UN agencies have recently made a much more serious commitment to satellite development through UNDP support of a detailed feasibility study for the Andean countries. The French government, too, has expressed a long-term interest in the potential use of educational satellites in Africa. Both India and Brazil are making serious commitments for the potential creation of national systems.

AID's future role will be significantly determined by whether or not there is sufficient developing country interest in any U.S. involvement. We will, in any case, probably continue to conduct studies that illuminate options, problems, and potential solutions. We will distribute our current studies by late 1972; they may provide some helpful guidance on planning, research, and policy questions.

We will also attempt to facilitate joint efforts during the early phases of development, associating projects elsewhere with similar efforts in the U.S. In 1973, for example, the ATS-F satellite is to be used for a U.S. educational experiment that will necessitate the investigation of many of the same questions that will be faced by India, Brazil, and the Andean countries. This first trial is an important opportunity for creating a process whereby we can all learn together. We hope to arrange a meeting of planners from these projects in 1972. Should there be interest in such a meeting, we will also, of course, continue to participate in the various forums, national and international, that address key policy issues in this area.

V. CONCLUDING NOTE

Within the next 2 - 5 years, there will be a substantial increase in the number of countries which will wish to engage seriously in demonstration and pilot projects in educational technology. A lesser number will wish to undertake full-scale operational projects as major national efforts at educational reform.

As has been noted, real progress in educational technology can only occur when there is an increasing number of projects in both of these categories. However, the problems inherent in demonstration and pilot projects should not be minimized. They must be confronted by both the developing countries and the prospective assistance agencies.

First, initial investments in such projects (particularly full-scale applications) are high; transition from an existing system to a radically different system causes instability and controversy; the time required for execution of this transition is relatively long -- perhaps five years is a minimum.

These problems demand on the part of the developing country a very high level of substantial resources for a number of years. If this is not forthcoming, it is questionable whether the project should be initiated at all.

Even if these conditions are met, the problems facing interested development assistance agencies are formidable. No such agency has unlimited resources and, in many instances, its resources of people properly qualified to assist such an enterprise are more unlimited than its funds.

These circumstances suggest consideration of some of the characteristics of projects that might merit the joint efforts and investments of development assistnace agencies.

For applications within the school system, continued experimentation with television will be important as systems are developed which are less reliant upon trained classroom teachers, which provide more opportunity for rapid student progress through the system, and in which operating costs can be reduced. Of greatest promise are systems like those planned in Korea, where television will be effectively tied into instructional modules keyed to the achievement of specific behavioral objectives.

Concurrently, we believe there should be expanded efforts to utilize other technologies, in appropriate combination, as the core of instructional systems, particularly technologies which are lower in both cost and operating complexity than television. Prime candidates at this time include radio, audio cassettes, microfiche, and printed forms of programmed instruction. To date, applications of these technologies have solely consisted of supplements to instruction. While there is question whether these technologies are dramatic enough and instructionally powerful enough to fulfill the role that television is playing in countries like EL Salvador and Niger, a reasonable working hypothesis is that such a role is possible. At the same time, it is necessary that they be used with a clear focus on the educational outcomes that are expected. This hypothesis may be of somewhat greater credibility if one considers the option of combining these technologies with some use of television or other equally motivating forms of communication.

For in-school applications, again, some trials should tentatively be planned near the end of this five-year period for the new video disc technologies or related video recording techniques which hold promise or providing relatively inexpensive television lesson material with a greater degree of flexibility than is provided by conventional broadcasts, which must be broadcast at a certain time, and which are constrained by limited television channel capacities.

As a secondary priority, a fuller investigation should be made of the prospect of demonstrating systems which can provide high quality, specialized instruction through whole courses or through more limited instruction modules distributed by various ways through the instructional technologies -- video recording, programmed instruction, audio cassettes, or computer-assisted instruction. The comparatively high present cost of instruction at these levels, together with the commonality of much professional subject matter throughout the world, suggests that such systems may be cost competitive with present expenditures and may also provide major improvements in quality, and a major expansion in opportunities for advanced training.

For out-of-school applications, the definition of projects is not yet clear. It is likely that they will encompass experimentation and demonstration involving many of the lower cost, lower complexity technologies, as well as some significant experimentation with television. Of greatest promise, at this point, is the possibility of providing a bank of information to communities in developing countries for both radio and video cassettes and a variety of programmed instruction materials in printed form. It is probably desirable that such projects attempt to integrate behavioral and social development programs across fields of functional activity -- maternal and child health care, agriculture, etc. -- through a concentration on the entire family group as the target audience. It is also likely that two kinds of projects will be attempted -- first, an effort to greatly expand the reach and impact of extension workers and other inter-personnel "change agents," and second, an effort to press the capacities of the instructional technologies to directly teach mass audiences, with a minimum or neglible amount of change-agent support.

In all these matters, the basic responsibility for policy and resources obviously must rest with the developing country. In most cases, however, external technical assistance and capital assistance will be required. This suggests the need for very close collaboration of the developing country and the assistance agencies in order that the right mix of resources are available -- in appropriate magnitude and at the right time.