Artificial Intelligence and its Implications for Education

By Laura Kann

Introduction

Twenty-two years ago the study of artificial intelligence (AI) had barely begun to crawl. An area of study fraught with controversy, diversity, and decentralized leadership and coordination, considerable progress has been made. AI is just now reaching the point whereby it can have crucial implications for all aspects of life. The home, industry, business, government, recreation, health care, and education will all be affected. This article will focus on the educational implications of AI, now and in the near future. Specific uses of AI will be illustrated and the issues surrounding these uses evaluated. However, in order to facilitate a more accurate perception of the issues and to provide equal footing from which to base evaluations on, several critical terms and somewhat philosophical issues need to be discussed first.

Essential Definitions

The most obvious place to start is with the term *artificial intelligence.* There are probably as many different definitions of this concept as there are people doing research in it. Nonetheless, there is general agreement that AI is a branch of advanced engineering, though not to be confused with the study of computers, which is computer science. Instead, AI is a study of computer programs (Boden, 1977). AI is also a cognitive science concerned with the nature of learning and language (Papert, 1980). It has also been identified as one of the three leading technological breakthroughs of modern times along with genetic engineering and microelectronics (Bernhard, 1980).

Definitions from leading researchers in the field begin to explain its scope and purposes somewhat more specifically. Margaret Boden, a philosopher from the University of Sussex, defines AI as the study of intelligence as computation or the development of a systematic theory of intellectual processes (Boden, 1977). Similarly, Seymour Papert, a mathematician with an extensive background in educational psychology, describes AI as the use of computational models to gain insight into human psychology and reflect on it as a source of ideas about how to make mechanisms emulate human intelligence (Papert, 1980). Robert Bernhard suggests that AI is the method by which behavorial scientists will develop the first detailed models of human thinking (Bernhard, 1980). Banerji Ranan offers yet another perspective by defining AI as the totality of attempts to make and understand machines that are able to perform tasks that, until recently, only human beings could perform, and to perform them with the effectiveness and speed comparable to a human (Banerji, 1969).

Donald Fink suggests that AI be defined very functionally as a) the ability of machines to organize information into meaningful patterns and to recognize, store, recall, and manipulate such patterns in playing games, solving problems, answering questions and in controlling the actions of other mechanisms; b) the ability of a machine to respond to patterns of stimulation, particularly those not forseen in its design; and c) the observed performance of such machines as measured by comparison with or in competition against human intelligence (Fink, 1966). However, the above definitions not withstanding, the most quoted and concise definition is that of Marvin Minsky of MIT who defines AI as *the science of making machines do things that people need intelligence to do* (The Seeds of Artificial Intelligence, 1980).

Another way to look at AI is to examine each term of the concept. "Artificial" can be easily defined as synthetic, man-made, or unnatural, terms most people apply to computers. But attempts to define "intelligence" simply and satisfactorily are considerably more difficult. Nonetheless, it is necessary to confront this definitional dilemma in order to firmly grasp the implications of AI and the controversies surrounding it.

Christopher Evans in **The Mighty Micro** (1980) defines intelligence as the ability of a system to adjust appropriately to a changing world. The greater its ability to adjust, that is its degree of versatility, the more intelligent that system is. As a general working definition this one is sufficient, but it does not deal with the more subtle facets of intelligence that are necessary for a true understanding of the concept. Therefore, Evans (1980) suggests six key factors that can be used to determine a system's degree of intelligence. While they are described in technological terms, they apply equally to all biological systems as well. The first key factor is data capture ability, which is a system's ability to extract information from the environment. Another important aspect of intelligence is data storage ability, that is, the ability of an entity to store information once it is captured and then refer to it in the future to improve its ability to adjust to the environment. The third critical part of intelligence is processing speed. This refers to the speed at which a system can process information and switch between basic units.

Software flexibility, the fourth factor, is probably the most important factor of intelligence. It can be described as the extent to which a system's software can be rapidly and easily modified. A fifth key factor of intelligence is software efficiency or how an entity adjusts to novel happenings in the environment. Finally, software range concerns the size and range of programs with which a system can be equipped and with which its central processor can cope. For all six key factors mentioned the more advanced they are in a system the more intelligent that system is. They can be used as a framework to judge one system's intelligence in comparison with another's.

Intelligence, Thinking and Learning

Man has evaluated intelligence in various ways for centuries. During the last sixty years the most common method has been the IQ test with scores projected on a scale from one to two hundred. For those not keen on the idea of a computer being intelligent, it should be a comfort to know that modern day computers would not earn more than a mere fraction of a point on a standard IQ test (Evans, 1980). However, it is also important to remember that man has had several hundred million years to develop, while computers have only been around for thirty years, and the field of AI even less. Moreover, at this point AI research is only concerned with making a computer intelligent. The other functions man has, and has had to put equal effort into developing, such as reproduction, defense, mobility, socialization, repair, and maintenance are not of concern to computers. Regardless of this present situation, what should be obvious is that the term "intelligence" is a complex one indeed and not one to be used lightly. Consequently, it will be used in quotations throughout the rest of this article.

Another issue of semantics the AI field deals with concerns the concept of thinking, usually with respect to the perennial question: can computers think? Alan Turing, the British genius and mathematician, while neither defining the term precisely nor answering the question unequivocally, did propose a solution that has generally settled the issue (Evans, 1980). His solution took the form of a test now called the Turing Test for Thinking Machines. The test is based on the idea that humans infer what others are thinking by the kind of conversation they can have with them.

The Turing Test basically involves two humans and one computer. One human serves as the judge or tester and in connected by computer terminals to the other human and to the computer being evaluated. The judge cannot know in the beginning which terminal is connected to which, but by typing messages into either terminal and by receiving messages back is to try to decide. A stupid computer will be easily revealed as such and the human will have no difficulty identifying it. On the other hand, if the judge cannot determine which terminal is connected to the computer then the computer will have passed the test and could be called a thinking machine. To date, though repeated attempts have been made, no computer has passed the Turing Test unconditionally.

This has only served to fuel the fire of the opponents to the concept of a thinking machine. Their arguments were first categorized by Turing and are essentially still the same today. They can be summarized as follows (Evans, 1980).

1) The Technological Objection — Man is a creation of God, and has been given a soul and the power of conscious thought. Machines are not spiritual beings, having no soul and thus must be incapable of thought.
2) The Head in the Sand Objection — This is really not an argument about why it cannot happen, but rather an expression of a wish that it never will, such as 'what a horrible idea!'
3) The Extra Sensory Objection — If there was such a thing as extrasensory perception and if it were is some way a function of human brains, then it can, also, be an important part of human thought. However, in the absence of any evidence proving that computers are telepathic, one must assume that they can never be capable of thinking.
4) The Personal Consciousness Objection — Not until a computer can write a sonnet or compose a concerto because of thoughts and emotions felt, not by the chance fall of symbols, and know that it had written it, can a machine be considered to be thinking.
5) The Unpredictability Objection — While humans behave and think unpredictably, computers are created according to a specific set of rules and operate only according to a specific script, therefore thinking must be an essentially human ability.
6) The 'See How Stupid They Are' Objection — Because of the many limitations computers now have there is no hope that they could ever think.
7) The 'Ah But It Can't Do That' Objection — This is an eternally regressing argument that continually adds a new challenge every time an earlier one is met.
8) The 'It Is Not Biological' Objection — Only living things can have the capacity for thought, so non-biological systems cannot possibly think.
9) The Mathematical Objection — Based on Kurt Gödel's theorem the argument follows that no matter how powerful a computer is it can never tackle every task on its own.
10) Lady Lovelace's Objection — A computer cannot do anything it has not been programmed to do.

Each of these arguments has been refuted by Turing as well as many other proponents of the thinking machine. To this group past failures merely imply that the technology necessary is not yet available, not that it never will be available (Dreyfus, 1980). Moreover, many computer programs with limited thinking abilities have been developed, as will be shown later.

Regardless of which side is right, there are negative implications for both. For example, if computers were proven unable to think then that would imply that a scientific account of thinking is not possible, that thinking is beyond the range of rational thought, and that those who do think must contain a non-mechanical or non-physical mysterious something. On the other hand, if computers were proven able to think, then man would be merely a wonderful rational thinker no better than a machine (Kugel, 1979). Both options pose interesting dilemmas, which is why the controversy is so heated at the present.

A final issue surrounding the field of AI that must be dealt with concerns the concept of learning. Just as the degrees of intelligence and thinking ability are used to evaluate an AI computer program so is its ability to learn. The term learning is typically defined as the capacity of a system to change its behavior as a consequence of experiences (Michie, 1974). However, the controversy does not concern this definition, but rather the theories for how learning, particularly the learning of language, takes place. AI work cuts across the age-old conflict about the relation between linguistic ability and other congnitive functions in the developing child. Questions concerning the domain-specificity of certain abilities, their relationship to particular brain structures, and their extent of innateness, all come into play when an AI researcher attempts to simulate or duplicate human "intelligence."

Typically, either the traditional Chomskian or Piagetian perspectives are used as frameworks for the AI computer programs. According to the Chomskian view each child is born with a definite linguistic competence that is extremely specific to language, has little overlap with other congnitive abilities, and is determined by innate biological structures. In contrast, the Piagetian perspective maintains that linguistic competence shares the major congnitive processes with other intellectual domains and is explicable in terms of the psychodevelopment process based predominately on unstructured experiences (The Seeds of Artificial Intelligence, 1980). Regardless of which point of view ever proves correct, AI has a direct bearing on the issue. For no complete model of human intelligence can ever be devised without a clear theoretical framework upon which to base it. Consequently, only a very few AI programs at this time exhibit any learning abilities.

Obviously the issues surrounding the field of AI are neither simplistic nor easily solved. As a result, their effect on the actual work done is great and will remain so until they are satisfactorily resolved. One of the primary areas toward which AI research is being directed, and one that confronts many of these issues directly, is education. To fully appreciate the impact that AI is having, and will be having, on education this paper will review the present and potential uses of computers in education.

Computers in Education

The use of computers in education has traditionally been in just two domains (Sugarman, 1978). The first of these is the use of computers for class scheduling, registration, payroll matters, and general record keeping. The other use of computers in education is computer aided instruction (CAI) or programmed instruction. CAI was first introduced into education in higher education and industrial training in the late 1950's when computers were still quite large, very slow, and had rather small memories by today's standards. While considered to be revolutionary at the time, CAI never fulfilled its initial promises. Compared to some present day computers those used initially for CAI can be considered stupid. They were typically employed to drill a large number of students in memorization exercises or to present material in small, highly structured pieces, each idea building on the last, and each piece followed by a simple question to facilitate integration. Today in primary and secondary schools, CAI is often integrated into foreign language and social classes studies. At the university level many introductory courses in mathematics or physics utilize the traditional CAI as a supplement to regular lectures.

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Regardless of their specific function most of the early CAI programs have two detrimental characteristics (Raphael, 1976). First, only one-way communication is allowed. Material is presented in a passive manner and the student is not allowed to interact with it in any original way. Secondly, because the computer does not allow significant two-way communication, the student is not encouraged to think. Many people feel that this is very detrimental to a student's natural initiative, originality, and creativity. Moreover, only a few studies show that students gain significantly from the factual information presented by CAI. With these restrictions in mind it is obvious why CAI's popularity suffered so severely in the late Seventies.

Fortunately, work in AI has progressed to such a point that some computer programs, while not yet capable of passing the Turing Test, have definitely become "intelligent" computers. AI has provided the second chance CAI was in desperate need of.

Applying AI to CAI

The new programs produced by AI research are based on the belief that a highly intelligent, empathetic, personal tutor can enhance the intellectual development of children, even if it is not a human but a computer (Raphael, 1976). Furthermore, the AI researchers realize that for learning to take place there is more involved than merely placing information in a student's memory (Norman, 1979). Therefore, the programs developed are highly sophisticated and have attempted to incorporate many of the best characteristics of the best human teachers. Criteria for an effective AI program for "intelligent" CAI include the ability to respond to two-way communication; to decide whether to generate a particular display; to test knowledge of a certain concept that previously posed problems to the student; to terminate an interactive session if the student's interest, motivation, or competency diminishes; to determine a sequence of experiments needed for the student to gather the best information; to select both difficult and easy paths toward a solution; to generate feedback dynamically; to improve performance over time; to possess a wide range of behavorial goals for the learner; and to present a structural description of the subject matter and performance criteria (Offir, 1976). There are basically seven applications of AI programs that have arisen from these criteria for "intelligent" CAI. While none are entirely exclusive of any other, each type does offer a slightly different emphasis or perspective.

The most successful and most widely implemented and evaluated AI programs for educating children are based on the principle that the child should control the computer rather than letting the computer control the child, as it traditionally does. A specific example of this, using a language called LOGO, is Turtle Geometry (Papert, 1980). Developed by Seymour Papert and his colleagues at the Artificial Intelligence Laboratory and Computer Science Laboratory at MIT during the early Seventies, Turtle Geometry is probably the first AI program designed particularly with the needs of children in mind. The language, LOGO, is non-mathematically oriented, simple to learn, based predominantly on symbols, but most importantly, sophisticated enough to be as powerful as many professional computer languages. The Turtle is, as Papert describes it, an "object to think with" (Papert, 1980, p. 11). More concretely, the Turtle is a computer controlled cybernetic animal that exists in the congnitive miniculture of the LOGO environment. It can be triangle on a computer screen or a mechanical object. The Turtle robot can run on the floor with a pencil in its center which can be lowered so that the turtle leaves a trail behind itself. Overtly, children use LOGO to program the Turtle to draw geometric shapes of the teacher's or their own choosing. This activity teaches them many principles and concepts of geometry. Indirectly, and probably most importantly, the children learn to verbalize their ideas in a concise manner, divide a task into manageable chunks, and correct and improve trial solutions progressively. In general, what the children develop as a result of their work with the Turtle is a very sophisticated style of problem solving applicable to any other school subject as well as all additional aspects of their lives. Moreover, they truly enjoy learning this way, which is something that cannot often be said for traditional teaching methods.

A second use of "intelligent" computer programs is called **mixed initiative computerized educational instruction** systems (Raphael, 1976). In this instance the computer acts as an active partner in the student's learning process. It does not merely feed facts to the student like the old CAI programs, nor is it programmed exclusively by the student as with Turtle Geometry. Instead, these programs use a fairly extensive knowledge base to facilitate the student's acquisition of the material. They can ask questions of the student based on past performance as well as answer questions posed by the student. Furthermore, these programs can understand natural language commands to a fairly sophisticated degree, sense student boredom or the need to change the pace of a course, and guide the work to areas the student needs the most help with.

One example of this type of "intelligent" program is called SCHOLAR (Raphael, 1976). SCHOLAR's specific domain is South America geography and meteorology. While it is undoubtably restricted, its knowledge base of the specific topics is extensive and is natural language understanding system is truly remarkable. Like Turtle Geometry it teaches advanced reasoning procedures as well as South American geography and meteorology.

Another example of the mixed initiative computerized educational instruction systems is SOPHIE, which tutors electronic troubleshooting (Bregar, 1980). Like SCHOLAR, though its domain is restricted, SOPHIE's understanding of natural language is very flexible. It can respond to questions students asks about actual or hypothetical situations, and analyzes students' responses by determining the consistency of their arguments. It also helps students to develop sound reasoning skills as well as competency with electronic circuits.

A third application of AI programs in education is called *expert programs* (The Seeds of Artificial Intelligence, 1980). These possess a substantial amount of knowledge about a given problem domain and, most importantly, the procedural skills necessary for solving such problems. They are not merely a computerized library that provides information, for they can manipulate the information in quite a sophisticated manner as well. Typically these AI programs are created in limited specialty areas of mathematics, the sciences, and particularly medicine, by an AI expert in conjunction with one or more human specialists in that field. A few examples include MOLGEN created to plan experiments in DNA manipulation, INTERNIST which is used to diagnose internal medical problems, and HEADMED that serves as a psychopharmacology advisor. Doctors use these programs for advice and confirmation of difficult medical diagnoses. So far, though they are not used widely, their success rate has been quite high. Nonetheless, the use of expert programs in education has been limited to the confirmation of practice diagnoses by students specializing in that particular field of medicine the computer is programmed in. However, with time, their use may be expanded to a wider range of less specific subjects so that they may be applicable to the general classroom as well.

"Intelligent" computer programs also have been developed to tutor experimentally based mathematics and physics courses (Raphael, 1976). This fourth form of AI program utilizes graphics extensively to simulate actual experimental conditions. By trying an experiment out first on the computer a student can save both time and resources. Students are also encouraged to hypothesize difficult or even impossible experiments to do in the laboratory, because the computer can simulate these results as well. For what would take hours to calculate and plot even with a hand held calculator, like the shape of curves as certain variables change or the behavior of balls under different conditions in a kinetics problem, the "intelligent" computer can do instantly. Computer simulations can even suggest further areas of exploration. Similar to the other types of "intelligent" computer programs discussed, these programs encourage student initiative and general problem solving skills.

A fifth way programs developed by AI research are being utilized for education is in teaching foreign languages (Raphael, 1976). In one instance the computer can operate a slide projector and a tape recorder, so that the student can hear the new word pronounced correctly, while at the same time associate it with an appropriate illustration. The number of words or the speed at which they are presented can be altered by either the computer or the student, for both are capable of detecting errors and areas in need of additional work. Once again good study and problem solving skills are emphasized. More technically advanced programs use visual representation of phonetic sound patterns to compare and contrast input by teacher and students or even the computer and students. This is especially helpful to students concerned with getting the proper accent for each word. These programs have also been used quite successfully to help deaf individuals to learn to speak. Traditional methods of depicting the appropriate sounds have often been widely misinterpreted by the deaf person and have thus resulted in very poor speech patterns.

The sixth use for the new "intelligent" computers in education is computerized homework (Raphael, 1976). These programs, often used in conjunction with math classes, present problems for students to work out. As students improve the difficulty of the problem increases. Each problem is composed of randomly selected numbers so that lessons can be repeated without the exact same problems being presented. Should the students find a certain problem particularly difficult they can ask for clues from the computer, or the computer will revert to an easier but similar problem and will slowly guide the student to the correct answer of the more difficult problem. Studies of this type of AI program show that more homework is completed in a much more enjoyable way, which probably leads to better course marks.

A final use for the "intelligent" computers developed by AI is the one most enjoyed by the students. Authoring programs allow students to create their own computerized lessons for other class members to use (Raphael, 1976). This activity requires students possess a thorough understanding of a topic regardless of its breadth, a competency with a computer language or at least an understanding of how a computer utilizes natural language, and most importantly, highly developed problem solving skills to debug the programs so that others can benefit from them. As with all the other uses for "intelligent" computers the problem solving skills are emphasized because of their applicability to all facets of life regardless of the specific problem at hand.

The Benefits

These seven examples of the use of AI for CAI demonstrate the many benefits that students could receive if these programs were to be implemented widely instead of in just the few laboratories and experimental settings now available. Specifically, the benefits of these programs in education can be summarized as follows.

First, they can reduce the number of computer elite (Boden, 1977). As our society becomes more reliant on computers those who can interact competently and comfortably with them will be at a definite advantage over those who cannot. It is important that children be introduced to computers at an early age and the school is the perfect setting for this to occur. Second, they can create an opportunity for students to think about their own thinking in a very helpful way (Boden, 1977). In order to program a computer and then debug the program students must take a positive attitude rather than a self defeating, negative one (Bregar, 1980). Furthermore, they must be able to describe verbally and concisely their reasoning, future plans, and the mistakes they have made. Few other school exercises require such precise and in depth analysis of the thought process (Raphael, 1976). Consequently, the student deliberately learns to imitate mechanical thinking and is able to articulate what mechanical thinking is and what it is not. This can lead to a greater confidence about the ability to choose a cognitive style that suits the problem, not to mention the realization that there is such a thing as a cognitive style in the first place. This is not to say that mechanical thinking is necessarily the best approach, though it may be in a mathematics class, but merely that through work with "intelligent" computers students will have the opportunity to learn to think articulately about their thinking with respect to the particular problem at hand.

Third, AI programs can produce an improvement in the understanding of the sciences and mathematics (Boden, 1977). A great number of students, particularly females, grow up with a serious fear and general apprehension to anything mathematically oriented. Commonly called mathophobia, this phenomenon tends to irreparably separate the humanities from the sciences within society. Two cultures arise from this situation, each set on strengthening the differences between the two. An early introduction and competency with computers allows mathematics to become a natural vocabulary, not in opposition to but complementary to the traditional linguistic language. As a result the gulf between the humanities and sciences could be lessened and ultimately society could retire the compartmentalized view of knowledge and learning and instead see how well each "side" could benefit the other. Less abstractly, students can realize how well each subject in school compliments the others and how much each has in common, for there are very few subjects that could not be taught to at least a minimal degree with an "intelligent" computer program (Papert, 1980). Fourth, these programs should produce an increase in the degree of student participation (Raphael, 1976). "Intelligent" computer programs by their very nature require a great deal of active student involvement. No longer can a student merely daydream through a teacher's lecture. Each idea presented by a computer must be acted upon by the student. When a student has complete charge of the programming even more involvement is required. A mere nod of the head in acquiescence will not encourage a computer to continue. Undoubtably, this makes a student a better learner by sharpening the concentration and attention spans and by reinforcing the idea that learning is most productive when it is an active process.

Whether or not AI's potential to positively effect education will be realized can only be speculated. Though the issues involved are many it is clear that any talk of the future must be based on the assumption that computer technology has not reached its peak that growth will continue (Evans, 1980). Improvements are needed in the programs' abilities to respond to natural language and in understanding of the human thought and reasoning processes in order for the programs to be truly interactive and "intelligent."

Some Objections and Concerns

Opponents to widespread "intelligent" computer use in the classroom fear that computers will take over the teacher's job. This is highly unlikely for computers are a long way from possessing all the necessary traits required to abolish the teaching profession as it is today. Nonetheless, computers will be used increasingly to supplement human lectures, provide unlimited individual attention and infinite patience, and to keep lessons moving at a pace beneficial to all (Raphael, 1976). Even if computers were to gain the technological sophistication necessary to take the teacher's place such a drastic change would likely occur very slowly to many impending factors in educational institutions (Sugarman, 1978). Undoubtably, the classroom is an artificial and inefficient learning environment, but one that was forced out of necessity to develop because certain essential subjects such as mathematics and writing could not be assimilated in informal environments. Clearly, only truly "intelligent" computers capable of passing Turing's rigorous test would ever allow modification of the learning environment so that the knowledge schools now try to teach could be learned without human mediated instruction (Papert, 1980).

Another concern of the critics of AI's applications to education is the present lack of standards by which computers operate in the classroom. They feel that any teaching tool professing to be as powerful as computers are should not be implemented widely without some kind of protective restrictions. While Orwellian images of children 'running wild,' 'drugging themselves,' or 'making life impossible for their parents' are probably exaggerated, they do exemplify an area in great need of attention (Papert, 1980). A lasting solution can be possible only when education becomes a true science and the real nature of learning is understood (Evans, 1980). Simple solutions in the past, such as Skinner's teaching machine, have been insufficient and have probably done more to confuse than to resolve the problem. At present teachers, AI researchers, and administrators subscribe to their own personal theories of learning regardless of their actual appropriateness to the specific teaching situation. Only time can tell whether or not those with the power will have enough foresight and insight to address the confusion before it is too late.

One other major issue raised by AI's opponents is whether or not the ability of people to do simple calculations will be lost due to the computer's greater efficiency and accuracy with computational skills (Evans, 1980). This may not be actually detrimental because, though at this point it is impossible to tell, many people feel that truly natural and interactive mathematical powers are already inhibited by the formal discipline of learning trivial computational rules. "Intelligent" computers, they argue, will free students from the need to learn these unnecessary skills in mathematics and other subjects, so that they can tackle higher levels of learning and understanding. Consequently, it is possible that as computers become more "intelligent" student intelligence will also increase. These more "intelligent" students will then develop even better computers in a never ending upward spiral (Raphael, 1976). While this totally limitless growth in computing is neither predicted nor desired by many at present, it is surely possible.

Conclusion

Even though AI's opponents present some very real problems demanding attention, it appears they will do little to stop or even slow AI research into educational applications. Consequently "intelligent" computer use in the classroom will probably have an even greater effect on the intellectual development of children than any other teaching tool or technology, including the television, previously devised (Papert, 1980). Obviously, the issues discussed earlier concerning intelligence, thinking, and learning will need to be settled and many technological and social obstacles must be overcome. However, with the present disillusionment with the current school system and the promises that AI's application to education have offered, little appears to be stopping the eventual widespread use of artificial intelligence in education.

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Meeting Learners' Needs Through Telecommunications: A Directory and Guide to Programs. Raymond J. Lewis American Association for Higher Education, 1983

The Coming Information Age. Wilson P. Dizard, Jr., Longman, 1982.

By Paul Hurly

The bountiful harvest of recent books concerned with the role of new media in education and society leaves educators and educational administrators with few excuses for being ill-informed. The following is a sample of some of the best of the new crop.

Robert P. Taylor gathered five of the most innovative educators using computers in the United States — Alfred Bork, Thomas Dwyer, Arthur Luehrmann, Seymour Papert and Patrick Suppes — to discuss their philosophies and approaches in **The Computer in the School: Tutor, Tool, Tutee.** Taylor conceived a tri-modal framework for analyzing the educational role of computers which these five pioneers describe.

As a **tutor** the computer tests student knowledge, provides remedial material, and manages the learning process. As a **tool** the computer is programmed to perform such functions as simulations or word processing. The **tutee** mode, which receives the greatest focus in the book, is when the student tutors the computer via a computer language. Beautifully conceived, Taylor's text provides an uplifting glimpse of the potential future direction of schooling and formal learning in North America.

A much broader range of educational technologies are scrutinized by the authors gathered by Sheehan in **Information Technology: Innovations and Applications.** By itself this book does not provide sufficiently detailed descriptions of the new technologies to assist those readers who are less well informed about computers and new media terminology. The strength of this book is its attention to the broader context in which decisions are made regarding the use of educational media and information technology.

Manfred Kochen and Carl Adams discuss the challenge of planning for the implementation of information technologies and responding educational to their impact on society. They also identify some benefits of information technologies for planners. Richard Evans provides an update of his 1968 study on resistances to innovation in higher education and suggests several pragmatic steps for overcoming the blockages. Despite the learned opinions of Sheehan and his colleagues, however, educational technologists may sense that information technologies will have a far greater impact on the typing pool than in the classroom domain of the professor.

In **Meeting Learners' Needs Through Telecommunications,** Raymond Lewis has provided impressive evidence that innovative media-based educational programs are alive, well and thriving. Using mail and telephone surveys Lewis compiled summaries of 70 educational programs at the college and university level which use CATV, interactive CATV, teleconferencing, videoconferencing, computers and computerconferencing, television and videotape media to serve the needs of a wide range of learners. Prose and point form summaries for each project cover a range of standard topics such as educational mission, problems encountered, delivery system, finances, administrative structure and observations about distance learning. This is an excellent directory for planners and administrators seeking models for implementing innovative telecommunication-based learning strategies for their institutions.

Planning for the successful implementation of information technologies, argues Wilson Dizard, Jr., requires strong central leadership and the participation of all, or as many as possible of the sub-groups in society. Otherwise, he states, we risk making decisions which will benefit elites and will ultimately undermine democratic freedoms.

In **The Coming Information Age** Dizard provides a summary of the development of computer, satellite and telephone communications in the United States, and the facts to demonstrate the economic preeminence of the telecommunications sector in the 1980's. His discussion of the follies of Washington bureaucratic communication planning and corporate gamesmanship underscores similar points made by John Wicklein in his largely ignored but insightful, **Electronic Nightmare.** Dizard's observations on the dangers awaiting society if corporate machinations, and government disarray, regarding telecommunications policies persists, will give Canadians considerable cause for anxiety. The recent track record of Francis Fox's DOC mandarins, and the CRTC, typify the frenetic approach to planning Dizard advises we must foresake. In this advice there is also a strong message for educational planners.

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