EDUCATIONAL TECHNOLOGY:
Review of the Field

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Preface

*Educational Technology: A Review of the Research* was written with the teacher, trainer, graduate student, professor, and media specialist in mind. It provides a brief, yet comprehensive, overview of the theories and research that support the use of technology in teaching and learning. In addition to providing a historical perspective on the research and theory foundations of the profession of educational technology, *Educational Technology: A Review of the Research* presents current research that constitutes the basis for use of newer technologies, such as a cross section of all research dealing with educational technology, not merely the positive studies. Specifically, this book includes:

- definitions of the educational technology terminology used by researchers;
- an overview and discussion of the influence of behaviorism, cognitive, communications, and system theories;
- a summary of the evolution of educational technology research and theory building;
- reviews and summaries of research on the production and use of media;
- summaries of research on attitude formation and change;
- over 200 references that represent the foundation of research and theory in educational technology.

*Educational Technology: A Review of the Research* is an essential reference for those who want an overview of the research and theory related to educational technology. It was reviewed by members of the Research and Theory Division of the Association for Educational Communications and Technology, and their comments were used to insure accuracy. *Educational Technology: A Review of the Research* provides an easy tool for those interested in research on the impact of technology in teaching and learning. This edition was revised by Mary Anderson based on comments from users.

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A Review of the Research

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INTRODUCTION

Educational media alone do not influence the achievement of students. Media permit the delivery and storage of instructional messages, but do not determine learning. Researchers who have attempted to demonstrate the superior influence of educational technologies on achievement have been unsuccessful. On the other hand, researchers who have attempted to identify the appropriate techniques of message organization and the correct process of instructional delivery with technology have been more in the mainstream of what is now considered appropriate. Researchers who in the past designed experiments that compared one medium to another have now realized that they did not report usable results. On the other hand, researchers who studied how mediated messages were designed and how technologies were used in teaching have published an important collection of practical and generalizable recommendations.

In 1983 in the Review of Educational Research, arguably the most prestigious journal that reports educational research, a paper was published that articulated what many now agree was the best summary of the previous seven decades of media research. This paper became one of the most widely cited references of the following decade, and clearly was the force behind a rethinking of research on and about educational technology. The paper was not widely accepted at first, and was the focus of a series of rebuttals that amounted to one of the most interesting controversies ever reported in educational technology literature. Many media practitioners who had a professional interest in demonstrating the superiority of mediated instruction were stunned to read that the research indicated that instructional media were not inherently "better," and many media researchers were disappointed to learn that their research efforts seemed to have been wasted.

At the heart of the Review of Educational Research article was an analogy that clearly established the theme of the entire paper. The author, Richard Clark, one of the most respected of technology researchers, later said that the fervor created after the publication of his paper demonstrated to him the power of an analogy. Clark stated that: "The best current evidence is that media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in nutrition...Only the content of the vehicle can influence achievement (Clark, 1983; p. 445)."

Clark then went on to convincingly substantiate his argument that media were not superior, but were techniques for message storage and delivery. Efforts to prove otherwise, Clark argued, were ill-conceived at best, or ignorant at worst. Clark's argument was so articulately presented and persuasively argued that there was a rush to read his entire paper.

In spite of the many counter attacks published in educational technology journals (Petkovich, M. & Tennyson, R. 1984; Kulik, J., Kulik, C., & Bangert-Downs, R., 1985; Cunningham, D. 1986.), Clark's premise about the relationship between educational technology and learning became widely accepted by those who studied it carefully. Since 1983, increasing numbers of researchers have recognized that media comparison studies are inappropriate, and that research efforts should be based on a new set of questions. For example, researchers have begun to design cost effectiveness and cost benefit studies, and media attributes and symbol systems have become central to experiments reported by others. Theory based and theory building research studies have always been considered central to appropriate scientific inquiry. Unfortunately, as Clark pointed out, many comparison studies of the last few decades ignored the importance of theories. Researchers either did not relate their studies to a theory, or they misinterpreted or misapplied what they thought was a theory. For example, many researchers thought Edgar Dale's (1946) Cone of Experience was the basis for an approach they called Realism Theory. Since the Cone of Experience listed media on a continuum from abstract to real, researchers attempted to demonstrate that media in the lower, more realistic levels of the Cone were "better." Actually, the Cone was not a theory. Rather, it was merely proposed by Dale as a way to logically organize media types. Researchers used this plan incorrectly, and while a number of studies based on it were interesting, they did not really improve on what was known about educational technology.
The following pages will explain a theory and research base that supports the effective and efficient use of educational technology. These theories are not the only ones used to provide direction to media research, but they are probably the most important. Systems and Communication Theories have been used to explain the relationships between the elements of instruction when media are used. Behaviorism and Cognitive Theory have been proposed by psychologists who have attempted to explain how learning occurs. These theories do not motivate researchers to try to identify the "best" medium. Rather, they provide direction for investigation of the processes and techniques for effective teaching and learning with media.

Definitions

In 1977, the Association for Educational Communications and Technology (AECT) published *Educational Technology: Definition and Glossary of Terms (ETD)*. This book clarified the terminology used in the field of educational technology and attempted to establish a foundation for clear discourse by researchers and practitioners. Educational technology (ET) was defined as a "complex, integrated process involving people, procedures, ideas, devices, and organization for analyzing problems and devising, implementing, evaluating, and managing solutions to those problems involved in all aspects of human learning" (p. 1). This definition was based on the Domain of Educational Technology (Figure 1), which clarified the components of the process of educational technology.

Several related terms were also defined. "Technology in education" was defined as "the application of technology to any of those processes involved in operating the institutions that house the education enterprise, including the application of technology to finance, scheduling, grading, and other processes that support education." Technology in education is not the same as educational technology.

Instructional technology (IT) is a sub-set of educational technology, based on the concept that instruction is a sub-set of education. The definition of instructional technology is the same as that for educational technology with one addition, instructional technology refers to situations where "learning is purposive and controlled." Because IT is narrower, and implies more specificity than educational technology, it is preferred by many media professionals.

Several concepts implied by the definitions of educational and instructional technology require clarification. ET and IT refer to considerably more than devices. Rather, the definitions concentrate on a process that may use devices. Those who practice educational technology and those who do research related to educational technology are interested in much more than things. They are most concerned with the process that produces predetermined learning outcomes. Also, educational technology is not synonymous with educational computing. There is a disconcerting tendency by some to equate the two terms, especially by those in governmental agencies. Educational computing is a subset of educational technology. They are not the same.

Second, clarifications of the definitions of ET and IT contained in ETD refer to a "systematic" process. The concepts of Systems Theory, which will be discussed below, are the foundation for this systematic process, and while several models for applying systems theory to education have been proposed by media practitioners, they are all based on the single process explained by general Systems Theory (Bertalanffy, 1968).

The definitions contained in ETD were developed after a number of years of work by a large committee of educational technologists. These definitions provide the basis for the organization and content of this paper. The following sections of the paper emphasize: the use of a theory base for defining research issues and designs in educational technology, the relationship of various educational technologies, salient approaches and findings in research on the uses of educational technologies, and future directions for educational technology research.

In the next section, the basic theories influencing research in educational technology are summarized. Following that is an overview of the basic types of research conducted in educational technology and a view of current and future directions in the area. In the fourth section of this paper, research in each of the basic areas of educational technology is reviewed; these areas are audio, still pictures, film, video, computer based learning, and hypermedia. In one sense the newest area of educational technology, hypermedia, combines research findings from all the other areas and emphasizes the interconnections of these areas and findings. Research on the use of educational technology for changing attitudes is contained in the fifth section. The final section summarizes the major findings identified in this paper and provides directions for future research in educational technology.
THEORIES, RESEARCH, AND EDUCATIONAL TECHNOLOGY

Introduction

A theory is a set of related propositions that suggest why events occur in the manner that they do. Theories are used because they:

• Provide patterns for the interpretation of data.

• Link one situation with others.

• Supply a framework within which concepts and variables have significance.

• Permit the interpretation of the larger meaning of situations.

The ultimate role of a theory is for it to become the predictor of events. When prediction becomes precise, a theory becomes a law. Scientists conduct research to test theories and to build theories. Basically, what they are doing is trying to identify the relationships between and among natural phenomena (Snelbecker, 1974).

Most educators feel that the complex nature of human behavior makes the development of laws of behavior, or laws of learning, unlikely. Scientists in all disciplines have always believed the concepts they were investigating were difficult, yet they continued their work anyway. Pre-classical chemists thought all matter was composed of earth, wind, water, and fire. Now, because of the efforts of many over hundreds of years, the chemistry of the physical world is considerably more comprehensively understood. Theory building is not easy, but it has proven to be one of the few successful techniques available to help scientists understand why events happen.

Over the years, a number of theories have been identified that give direction to the practice of education generally, and educational technology, specifically. Most notable among these are systems theory, communication theory, behaviorism, and cognitive theory, all of which were products of an approach called scientific empiricism.

Scientific empiricism is at the root of modern scientific inquiry. Research, as it is most often practiced, is an attempt to discover the laws of nature. Scientific empiricists are realists who believe that natural laws exist in closed systems that when clearly understood can be used to solve problems. Scientists believe that two components of reality, objectivity and causality, make discovering natural relationships possible (Jonassen, 1983). The objectivity of nature makes scientists believe they can observe and describe the physical world, which is believed to be an orderly place that is predictable and generalizable (Jonassen, 1984). The belief in causality of events means that things do not happen by chance, but are the result of some natural force. Scientists objectively observe events and make predictions about their cause. As a result of this process it is possible to learn why things happen, to predict what will happen, and to even make events happen.

The tool of the scientific empiricist is the scientific method. The scientific method generally has these steps:

1. Statement of the problem.

2. Hypotheses as to the cause of the problem.

3. Experiments to test each hypothesis.

4. Predicted results of each experiment.

5. Observed results of the experiments.

6. Conclusions based on the results of the experiments.

As Pirsig (1974) said in his classic book, Zen and the Art of Motorcycle Maintenance, "the real purpose of the scientific method is to make sure Nature hasn't misled you into thinking you know something you don't actually
know. There's not a mechanic, or scientist, or technician alive who hasn't suffered from that ... One must be extremely careful and rigidly logical when dealing with Nature: one logical slip and an entire scientific edifice comes tumbling down (p. 101)." Scientists use the scientific method, based on the theory of scientific empiricism, to develop other useful theories which, in turn, are also tested using the scientific method.

One problem identified at the root of many of the comparison studies reported in the literature of the 60s and 70s was the lack of a theory base for the approach used. Theories were often ignored when experiments were designed and when results were reported. Researchers did not have a clearly identified, broadly based structure in which to work. Recently, two categories of theories have become fundamental to educational technology. The first deals with the environment within which technology is used. Systems theory and communication theory are the most important in this category. The second area of emphasis deals with the application of the psychological theories of learning to education. Behaviorism and cognitive theory provide guidance for researchers in this category.

Theory Bases: Systems and Communication Theory

Researchers who have looked at the processes behind the use of technology in education have often used two closely related theories as the basis for their efforts. Both systems theory and communication theory attempt to show the relationships between the elements of entire entities, and both provide direction for those who have attempted to relate technology to other components of the education process.

SYSTEMS THEORY

In its broadest conceptualization, systems theory concerns the organization and structure of entire organisms. A biologist, Otto von Bertalanffy (1968), is credited with stating the theoretical foundations of systems theory. This foundation is based on the scientific exploration of wholes and wholeness, and on the study of their structure and stability. Systems theorists state that the components of events should be identified and their impact measured. For example, environmentalists believe that the whole earth is a closed system and that events in one country influence the environment in all other areas: Chemical use in the United States will ultimately influence not only the ecology there, but to a lesser extent will have an impact on the rest of the world. Advocates of systems theory believe that it is possible to describe phenomena in the world accurately and to predict future events based on these observations (Romiszowski, 1981).

Systems theory was developed in the first third of the 20th century, as a direct consequence of the increased importance and acceptance of science and the scientific method. As scientists began to solve problems effectively, their methods were widely studied and applied to new areas of concern. Systems theory was an attempt to clearly state a procedure for describing how real-world events interacted. It was hypothesized that systems principles would be usable in a variety of situations, not just those involving scientific research or technology development.

Systems theory was made practical to educators by the development of the systems approach. This technique was a translation of the principles of general systems theory into a procedure for the applied field of teaching. The systems approach is a kind of cookbook of steps for designing instruction. The systems approach is based on the following ideas:

• The systems approach applies to learning a method of logical problem solving similar to the scientific method.

• Instruction designed using the systems approach is self-correcting.

• Instruction developed using the systems approach applies rational procedures for designing instructional programs that ensure the attainment of specific behavioral objectives.

• The systems approach incorporates ways of looking at complex organizational problems that takes into account all contingencies.

The systems approach is intended to be prescriptive rather than explanatory. It gives instructional planners a rational procedure to follow when instruction is designed and developed. The systems approach is based on one important principle, a belief in the natural order and rationality of the world. Systems planners are scientific empiricists. The systems approach gives educators a procedure for using what is known about learners and learning
in the design of instruction. This is primarily because of its emphasis on the study of wholes and wholeness. The systems approach is a basic technique used by educational technologists.

One of the most widespread applications of the systems approach is the technique advocated by proponents of the Michigan State University instructional development model, which is a three-part, nine-step procedure for designing instruction. It was developed at Michigan State University in the 1960s (Figure 2).

The systems approach to instructional development is actually a series of steps that guide the developer of instruction in the design of learning activities. Stage I in this model is called system definition. This stage refers to the start-up activities that must be planned and organized. First, the instructional problem in terms of a broad goal is identified. Next, the setting, or instructional situation, is analyzed. Information about students, such as background knowledge, learning styles, and motivation are matched to instructional resources and teaching strategies. Last, the procedures used to manage the instructional activities are organized.

Stage II is called the system design stage. Here, specific performance standards, materials specifications, and design limits are stated. Precise behavioral objectives are written, teaching methods are identified, materials are chosen or developed, and the entire instructional procedure is designed. This instructional plan is called a prototype because it is tested and revised in Stage III of the instructional development approach.

Stage III, the system evaluation stage, identifies evaluation procedures. During this stage, prototype instructional materials and techniques are evaluated and revised. The revision process continues until the validity of the new instructional system is determined. Feedback connects all stages in the process. In the context of the systems approach, feedback refers to information that is used to make adjustments to the instructional materials and procedures.

The systems approach for instructional design is behaviorally oriented. It strongly advocates the application of behaviorist principles such as the pre-assessment of the target audience, the use of objectives stated in terms of expected outcomes, and the use of feedback.

Systems theory, the systems approach, and the instructional development model give considerable guidance to educators interested in designing or evaluating instruction (Dick & Carey, 1985). Preplanning, audience assessment, feedback, interaction between elements of the system (student and lesson), and use of performance-based objectives are techniques that have been derived from systems theory that are routinely used to develop instructional media. Systems theory gives educators a prescription for designing effective lessons. While not universally applicable, it does provide considerable direction to educators interested in differentiating between ineffective materials and techniques, and those likely to be more successful. One additional adaptation of systems theory that influences research about educational technology is communication theory.

**COMMUNICATION THEORY**

Communication theory was being developed about the same time that general systems theory was emerging. Communication theory is based on scientific studies that examine all the components influencing communication. In other words, it attempts to explain and account for all the phenomena related to and having an impact on communication. Communication theorists based their effort on von Bertalanffy's systems theory and contributed to his work by expanding the understanding of the role of feedback in systems.

Simple communication deals with the interaction of the individual and the environment, and is possible because the senses react to stimuli. The senses become conduits to the environment. For example, light waves fall on the retina of the eye. Perception occurs when stimuli are transmitted to and received by the brain. Perception is often referred to as the process by which individuals become aware of themselves and of the world. During perception, the brain receives stimuli and attempts to understand them. Perception involves intuition and is a cognitive process.

Recognition, the next step in simple communication, occurs when perceptions become familiar. What is perceived today is recognized tomorrow. Perceptions are experiences. They build on one another and become foundations for higher level understanding. Children, because they are constantly participating in new experiences, are often studied to learn about perception and recognition. In 1946, Edgar Dale reported on an article in the British Weekly by
Edward Vernon that listed what young children said were the "loveliest things they knew, people not included." Some of their replies were:

• The smell of rain.
• Cool wind on a hot day.
• Climbing uphill and looking down.
• Rain on your cheeks.
• Our dog's eyes.
• The crunch of dry leaves when you walk through them.
• The feel of running.
• The taste of strawberries.
• The feel of a dive.
• The smell of new mown hay.

These statements are examples of the process of reception and recognition. Complex communication includes reception and recognition but requires two or more individuals. One of the persons in the communication process, called the sender, has a message or an idea that he or she wants someone else to have or know. The second person in the communication process is called the receiver. How messages are relayed from senders to receivers is what communication theorists study.

The process of communication was formalized by Claude Shannon and Warren Weaver in their book titled, The Mathematical Theory of Communication (1949; Figure 3). The original Shannon-Weaver model was linear. Later, other theorists added the concepts of feedback and overlapping fields of experience to more accurately describe what happens during communication (see Figure 4; Simonson & Volker, 1984).

Fields of experience refer to all events that an individual has perceived, recognized, or communicated, and includes such things as language, cultural background, and education. Communication occurs in the area of overlap between the sender's experiences and the receiver's experiences. If a message is prepared that is not based on what the sender and receiver have in common, then it is unlikely that the communication process will be successful.

The sender is the individual who wants to communicate something. The task of the sender is to prepare a message that informs or influences the receiver toward the objective of the message. Obviously, in education the sender is usually the teacher.

The message is the idea the sender wishes to convey. This idea is coded in some transmittable form, usually involving symbols such as words or pictures. Symbols serve as clues to the meaning of the message. It is in the coding and decoding of messages where many of the problems of communication are found. Generally, the more realistic or familiar the symbols are to the receiver, the more successful the communication process will be. The receiver must be able to easily, quickly, and accurately decode the message into the idea originally held by the sender.

The channel is considered to be the vehicle for carrying the message. There are two categories of channels—sensory and technological. Sensory channels are those involving the five senses. Teachers talk to their classes. Dinner speakers use gestures to visualize ideas, and lovers touch to show their feelings. Sensory channels are generally quite limited. Voices can be heard only over short distances, and gestures convey only limited meanings. Touching, tasting, and smelling are limited in both variability and because of the need for close proximity between the sender and receiver. Sight is the most complex of the senses. However, the eyes only receive messages, just as the voice is used only to send messages.
Technological channels extend the senses. Radio waves can be used to carry information such as sounds, sights, or data over great distances. Words and pictures, written and drawn, permit the storage and transmission of information, and magnetic media are capable of storing sounds, pictures, and information virtually unaltered for use at a different time or in a different place. Technologies greatly expand and extend the message delivery capabilities of the teacher.

Noise refers to anything that interferes with the delivery of the message. Noise occurs because of the improper encoding of messages, because static is picked-up during transmission, or because something distracts the receiver from the message. The impact of noise is reduced by repeating the message, by sending it over several channels, or by using feedback to clarify the message's content.

The receiver is the target of the communication process. Often the sender and the receiver alternate their roles during communication, especially during feedback. Feedback permits a measure of control over the communication process because the sender obtains information about how successful the communication process has been. Feedback can be formal, such as testing or questioning, or informal, such as when teachers pay attention to students' body language or facial expression.

Communication is the process of message delivery. Communication theory attempts to explain this process. Obviously, systems theory is closely related to communication theory. Both are fundamental approaches examined by researchers who have attempted to understand the process of teaching and learning with technology.

Theory Bases: Behaviorism and Cognitive Theory

BEHAVIORISM

Of the theories supporting the use of technology in education, behaviorism has historically had the greatest impact. Behaviorism was used as the basis for designing early audio-visual materials and was the impetus behind many related teaching strategies, such as the use of teaching machines and programmed texts. Thorndike's connectionism, Pavlov's classical conditioning, and Skinner's operant conditioning were ideas used to give direction to early researchers who examined the impact of educational technology on behavior (Skinner, 1954; Thorndike, 1969), and to early developers who produced teaching materials for use in the schools.

The use of behaviorism in education is based on the principle that instruction should be designed to produce observable and quantifiable actions by the learner. Behaviorists consider the mental state of a learner to be merely a predisposition. Because mental states can not be observed, behaviorists do not believe teaching should be directed toward strengthening the mind, a common goal of educators of the early 20th century, but should be aimed at producing desirable outcomes in students. In other words, behaviorists expect any effective instructional activity, such as a computer-based tutorial, to change the student in some obvious and measurable way. After completing a lesson, students should be able to do something that they could not do, or could not do as well, before the lesson.

The theorist most closely associated with behaviorism is B.F. Skinner. He did more to popularize this theory than anyone, primarily because of his interesting research, but also because of his flair for publicity.

Because he was a scientific empiricist, Skinner viewed the study of learning as a science. Skinner believed that there were two types of learning. The first was Pavlov's classical conditioning, where a stimulus was applied to an organism to produce a response. Learning would occur when there was a transfer of stimulus control for a response, from one stimulus to another stimulus.

The second kind of learning, and the category most often associated with Skinner, is called operant conditioning. This approach for producing behavior change uses no identifiable stimulus before a response, but rather, uses reinforcers that follow a response or that are produced by a response. These reinforcers are responsible for a behavior change. Operant conditioning includes the use of reinforcement to promote desirable changes in behavior. Reinforcement occurs after desired actions.

For example, a science teacher might have students participate in a series of very organized laboratory exercises. The first few activities might be computer lessons that permit very little student variation but that praise the student
when correct answers are given. These computer lessons would give cues to the student to ensure success. Later, as students become more knowledgeable and confident, the cues would be gradually removed so that in future laboratory exercises they could work on their own. The science student would be conditioned to complete sequential science procedures without the need for prompting.

Skinner's contributions to the practice of educational technology are numerous. They include the following techniques:

• Stating objectives in terms of desired terminal behaviors.

• Assessing a student's previously acquired behaviors before any instruction.

• Placing a learner in a sequence of instruction where he or she can achieve at the 90% level.

• Using teaching machines to reinforce and to strengthen desired terminal behaviors.

• Recording a learner's progress through a lesson to gain feedback for revising the lesson.

Skinner was a vocal advocate of behaviorist principles and of the use of machines to teach. As late as 1986 he reiterated his belief that behaviorism was a critical theory for educators to understand and apply. He also advocated the use of computers in education because he believed that when computers were correctly programmed, they became ideal teaching machines.

Behaviorism has had considerable impact on education in general and on educational technology specifically. First, and most important, is the behaviorist principle that all instruction should be designed to produce observable and measurable outcomes in students. Instruction should be based on objectives that state clearly what is expected of the learner. Next, behaviorist thought promotes the use of pre-assessment of students so they can be placed in an instructional sequence at the point where they can achieve at a 90% level. Following pre-assessment, students are expected to continue participating in learning activities until they can demonstrate a 90% proficiency level on their new material. This 90% principle is one of the basic tenets of the mastery learning movement, a subcategory of behaviorist theory.

Behaviorism tells instructional developers that cues should be used to prepare students for information that follows. Small "chunks" of information should be presented by lessons, and students should be reinforced positively when success at learning is demonstrated. This means that interactive learning between the student and the medium is critical. Additionally, instruction based on behaviorist principles should allow for the collection of information from students as they learn. For example, if a student using a tutorial dealing with the Pythagorean Theorem constantly has problems with the algebra involved, then the lesson should route the student to a subsection that reteaches basic mathematics. This information, a type of feedback, should be used to modify the lesson and to monitor the student's progress. Last, student learning should be measured, and students who do not "measure up" should be required to work through the same or a similar lesson until their competency level meets minimum expectations.

To some, there is much about behaviorism that is unattractive. Because of its emphasis on outcomes, behaviorism is criticized as dehumanizing the teaching and learning process. Behaviorists counter this argument by saying that the emphasis on behaviors need not be at the exclusion of the affective dimension of education, and, as a matter of fact, behaviorists have developed taxonomies and behavioral objectives for attitudes. At any rate, educational technology owes a great deal to the principles advocated by Skinner and other behaviorists.

COGNITIVE THEORY

Educational psychologists and learning theorists have begun to move away from the behaviorist approach and have advocated a closer look at the internal processes that take place in learners during instruction. Behaviorists tend to ignore the cognitive changes that internally occur during learning. They maintain that it is impossible to design instruction based on what happens in a learner's brain because these changes are not observable or measurable, and
are impossible to predict. On the other hand, cognitive psychologists, the common name for advocates of cognitive theory, focus attention on the learning process itself and attribute a greater degree of autonomy and initiative to the learner than do behaviorists (Bruner, 1960; Carey 1986; Hilgard & Bower, 1975).

Cognitive theory concentrates on the conceptualization of students' learning processes. It focuses on the exploration of the way information is received, organized, retained, and used by the brain. When instruction is designed, proponents of cognitive theory believe that the cognitive structure of the learner, and groups of learners, should be taken into account. Several persons have been influential in advocating the cognitive approach, including Jerome Bruner, Jean Piaget, and Seymour Papert.

Many consider Bruner (1960) to be one of the primary advocates of cognitive theory. He has proposed that much of behavior depends on how we structure knowledge about ourselves and the world around us. Cognitive theorists believe that instruction must be based on a student's existing state of mental organization, or schema. How knowledge is internally structured or organized by a student has considerable impact on whether new learning will occur. New learning is based on using prior knowledge to understand new situations, and changing prior knowledge structures to deal with new situations. According to cognitive theory, information must be organized in a way that helps learners connect the new information with current knowledge in a meaningful way.

Bruner and other cognitive theorists concentrate on several concepts. First, they are interested in how knowledge is organized and structured. Second, they are interested in readiness for learning. Third, cognitive theorists value intuition. By intuition, Bruner means the intellectual techniques used for arriving at plausible but tentative conclusions without going through a series of analytical steps. In other words, the value of the "educated guess" is recognized. Last, the importance of motivation, or desire to learn, is identified. Specifically, cognitive scientists accept the importance of students having positive attitudes toward learning.

Cognitive psychologists view the learner as an active participant in the learning process, believing that learning occurs because the student actively participates in understanding and interpreting the learning environment. Thus, to the cognitive psychologist, education consists of enabling active mental exploration of complex environments.

Cognitive theory gives several guidelines to educators interested in designing or evaluating mediated instruction, and to scientists interested in planning research. They are:

• Predisposition to learning is important. Instruction needs something to get it started, something to keep it going, and something to keep it from being random. Jerome Bruner would call this activation, maintenance, and direction.

• The learner must be actively engaged in the learning process; students create knowledge by making connections with previously learned material. Learning environments must allow and encourage students to make these connections.

• The structure and form of knowledge must be considered. Specifically, the body of materials to be learned should be organized in some optimal way. Cognitive theory is partially based on the concept that children are first able to understand concrete operations, then graphic representations of reality, and finally abstract verbal and numerical symbols. Edgar Dale (1946) formalized this concept with his Cone of Experience, which organized experiences in 12 levels of increasing abstraction. Dale stated that before learners could understand abstract experiences they would require a sufficient depth and breadth of more realistic experiences. Children would not understand a computer-generated drawing of a flower unless they had first experienced real flowers.

• Sequencing of instructional material is important. Sequencing must take into account the limited capabilities of learners to process information. Because a child's cognitive style may partially determine success in learning activities, many educators in recent years have begun to attempt to identify the components of the cognitive styles of learners, such as their brain hemisphere dominance, their level of field dependence, and their visual processing ability.

• New information should be connected in a meaningful way to information previously learned. Use of advance organizers prior to instruction provides one approach to helping students connect new learning with previously learned material.
• Discovery learning is one important technique that applies much of cognitive theory. As an educational method, discovery learning consists of inserting learners into educational situations without articulating to the student what is already known about that situation. The assumption is that with minimal help from the teacher the student will learn more by discovering the lesson found in the situation. Papert's Logo language (Papert, 1980) is an excellent example of a computer-based tool often used to teach problem solving by discovery learning.

In summary, cognitive theory provides educators with a missing piece of the puzzle. Where behaviorists look at outcomes, cognitive theorists look at learners and processes. Although current work in educational research is increasingly based on the paradigms of cognitive theory, both theories provide important grounding for empirical work.

IMPLICATIONS OF BEHAVIORISM AND COGNITIVE THEORY

There are two important purposes for a theory base. First, theories provide a direction to research. Theories are based on research results, but they are not static. They continue to evolve as new research findings are reported. Theories are used as guides for scientists who continue to examine what the theories imply in an attempt to clarify them. Ultimately, scientists strive for the development of laws that can be accurately and widely applied to solve problems.

Second, theories provide direction to the practice of a profession. Specifically, behaviorism and cognitive theory guide developers of educational technology. They also give teachers a sound basis for evaluating materials developed by others. Traditionally, behaviorism has been the primary theory used to support the application of technology to learning. Increasingly however, cognitive science is becoming most important.

Even a superficial examination of behaviorism and cognitive theory reveals commonalities. Most obvious is the importance of feedback. A behaviorist would advocate the use of feedback to modify behavior, and cognitive theorists recognize the importance of correctly timed, positive feedback as a mechanism for supporting correct mental functioning.

Another area of common ground is the importance of the assessment of learners so that they can be assigned to instruction appropriate for them. Cognitive theory advocates the importance of determining as much as possible about the learner, and the process used by the learner to internalize information so that instruction can be optimally designed. Behaviorists have different reasons for advocating the importance of pre-assessing students, specifically to determine if they are ready for a lesson.

Phye and Andre (1986) compared behaviorism to cognitive theory (Table 1). They said about their comparison, "This contrast of behavioral and traditional cognitive views is overdrawn for the pedagogical purpose of making the distinctions between the views clear. The contrasting views might be conceptualized as endpoints on a continuum upon which the specific theories of behavioral and cognitive theorists would fall. This description does not do justice to the rich traditions within either behavioral or traditional cognitive psychology and does not provide an adequate historical perspective " (p. 3).

In summary, a number of instructional techniques are supported by behaviorism and cognitive theory:

• There should be a clear statement of the level of competence a student must have in order to successfully begin the lesson.

• Materials should provide for timely, individualized, and positive feedback.

• Outcomes of instruction should be clearly stated, probably in terms of student performance.

• Lessons should individualize both the rate and the route of teaching. Progress through a lesson should be based on the needs of the student who is being taught.
• There should be mechanisms to provide for multiple contingencies that might affect the successful completion of the lesson. Specifically, the ultimate technology-based system should be an intelligent one that "learns" as it is used.

• Instruction should be motivating to the learner, both cognitively and affectively. It should be both informative and interesting.

• Active involvement by the learner is important. Both intellectual and psychomotor involvement should be required of the learner.

• The learner should be assessed continuously. Students should know how well they are doing, not only at the end of lessons but also during lessons.

• The sequence of lessons should be logical and based on the needs of the learner. The route and rate taken by a student during instruction should not be left merely to the discretion of the learner.

• Some instruction should give students the opportunity to demonstrate their intuitive abilities.

Certainly, these guidelines are only general explanations of what behaviorism and cognitive theory say. Some educators would even consider it improper to try to identify similarities between these theories. Inherent in the process of theory building, however, is a certain amount of risk taking and hypothesis building.

One simple yet fairly accurate way to relate these theories to one another is to apply each to something familiar, such as getting a good picture on a color television set. A behaviorist would be content with adjusting the knobs and controls on the television. Behaviorists work with the situation at hand and manipulate it to get results. Getting the best picture possible would be the major concern of the behaviorist. The cognitive theorist, on the other hand, would use special scopes and monitoring devices to examine every tube and transistor inside the television. The cognitive theorist would try to examine the video signal to be sure it was being correctly processed by the television's electronic parts. Faulty or weak components would be identified and replaced. How the television manipulated the signal would be of paramount importance to the cognitive theorist.

In a teaching situation, the behaviorist wants to take the learner and produce the desired behaviors by controlling the learning environment. Manipulating the learner and learning situation to produce the desired outcome would be most important to the behaviorist. The cognitive theorist would want to study the brain and its functioning to see how learning occurs. This information would then be used to produce learning in students.

Behaviorism is the most practical, easily applied of the two theories. It is also probably the least sophisticated. Cognitive theory is the more elaborate theory, but not all of the scopes and monitors needed to study the brain are available to the educator. Ultimately, cognitive psychology may offer the most to researchers, teachers, and developers of instructional materials.

BACKGROUND - EDUCATIONAL TECHNOLOGY RESEARCH

Introduction

Research on technology in education has been reported for nearly 90 years. As media have evolved over this period, so have questions about and experiments studying the role of technology in educational situations. Four types of studies have dominated the research of media in education: evaluation research, comparison studies, intra-medium studies, and aptitude treatment interaction research. Other less pervasive types of research, which we will call alternative studies, have also influenced and will continue to influence the research on technology in education. This section will provide a background for the research on educational technology by providing an overview of the five kinds of educational media research.

Evaluation Research

Evaluation research studies are typically the first kind of research conducted when a new instructional medium is introduced. Every medium used for educational purposes at one time or another is studied to test its effects on
learning. The question that researchers seek to answer in these studies is "can people learn from messages presented by this medium?".

Most recently, researchers experimented to discover if people could learn from computers. The results were the same as the results of similar studies conducted with other forms of media; people can learn from computers (Salomon & Gardner, 1986). In fact, Levie and Dickie (1973) stated that people can learn from a variety of media. They implied, 10 years before Clark (1983), that it is not the medium alone that effects learning, but rather the content presented by the medium as well as other instructional variables.

Traditional media research has a strong link to behaviorism. Many early researchers considered learners as reactive, responding to external stimuli which were designed to control their behavior. Many early researchers viewed learning as a modification of behavior. These researchers operated on the belief that media in instruction offered great advantages in increased control of learning behaviors (Clark & Surgrue, 1988).

This behaviorist tendency of educational media researchers was derived from the research perspectives of early social psychologists (the first communication scientists), who concentrated their research endeavors on the effects mass media had on audiences (Rogers, 1986). Communication effects research, as it was called, examined the changes in a person's behavior that occurred as a result of the transmission of a message. The communication effects viewpoint was prevalent among social psychologists for the first half of the century and was most evident in the Bullet Theory, an early category of communication theory that said that mass media had direct, immediate, and powerful effects. More specifically, the Bullet Theory of communication effects stated that:

- Media present messages to the members of a mass society who perceive or interpret the messages similarly.
- Messages carried by media are stimuli that strongly influence the emotions of individuals.
- Stimuli lead individuals to respond in a uniform manner, creating changes in thoughts and actions.
- Because of a uniform mass society, the effects of mass communication media are powerful and direct (Lowrey & De Fleur, 1983).

For example, the Bullet Theory, applied during World War I, was used by newspapers to make people believe that the enemy was immoral and brutal. Stories of great atrocities played on the fears and other emotions of the masses. Such stories described the hideous behavior of the enemy and convinced populations on each side that those whom they opposed were wicked (Lowery & De Fleur, 1983).

Research on the uses of various forms of traditional mass media in the classroom tended to follow the procedures of early communication theorists. In the late 1950s and in the 1960s, many studies were conducted to evaluate the use of television in education. In their review of research on television in education, Chu and Schramm (1967) reported that hundreds of studies had been conducted evaluating the effectiveness of television in education. Chu and Schramm (1967) found that given favorable conditions, students learn efficiently from instructional television. For example, Sykes (1964) compared 58 education majors who had been randomly assigned either to a television group or a control group. The television group watched six 45-minute art lessons over six weeks, while the control group received instruction through traditional means. A post-test showed a significant difference in learning in favor of the television group.

Similar studies in a variety of educational environments and levels confirmed that students learn from instructional television. For example, Enders (1960) compared two groups of sixth-grade children who had received a series of science lessons via television to a control group that did not view the television programs. Both groups who received television instruction showed significantly greater improvement in learning than the control group. In an experiment conducted in an interracial neighborhood in New York City, Langdale (1962) found that closed-circuit television was an effective medium for teaching English to Spanish-speaking people, and Spanish to English-speaking people.

Summarizing their review of television and radio research, Chu and Schramm (1967) generalized that given favorable conditions, students can learn from any instructional media. This evaluation research finding has also been confirmed in research studies designed to compare media. For example, Kulik and Kulik (1986) performed a
meta-analytic review of 101 computer-based education (CBE) studies. The studies reviewed generally were one of two research types: evaluation studies (designed to examine the effectiveness of CBE in specific environments) or comparison studies. Although the majority of the studies were designed to compare media, researchers also tested whether or not students could learn from computers. The data suggested that CBE made significant contributions to students' academic achievement and also had a positive effect on student attitudes. In terms of evaluation research, the results indicated that people could learn from computers.

Typically, evaluation studies about media have indicated that learning can take place with any medium.

Media Comparison Studies

The most prevalent studies of media use in education have been media comparison studies. First reported at the turn of the century, media comparison studies were aimed at comparing the effects on learning one medium had as compared to another. The goal was to generate results indicating if one medium had a greater effect on learning than another.

One of the first major media comparison studies was conducted at the University of Chicago and examined the use of motion pictures in public schools (Freeman, 1924). The series of experiments, which ran for more than three years in eight public school systems, compared the effects of film with conventional instruction and with other forms of visual media (slide, stereographs, and still pictures). The study produced the following conclusions:

• The relative effectiveness of verbal instruction as contrasted with the various forms of concrete or realistic material in visual media depended on the nature of the instruction and the character of the learner's previous experience with objective material.

• The comparison of the film with other visual media (slides, stereographs, still pictures) as means of instruction when the variable was motion indicated that the film was superior within a restricted range and type of content, but that outside of this range the other media were as effective or more effective.

• The peculiar value of a film lay not in its generally stimulating effect, but in its ability to furnish a particular type of experience.

• Each of the so-called conventional forms of instruction that employed visual media had some advantages and some disadvantages, and there were circumstances under which each was the best form to use.

The results of the Chicago film studies should have directed media researchers away from media comparison studies because they indicated that the medium was not the important component effecting learning, but that other variables of instruction, such as learner characteristics and instructional content, significantly influenced learning. However, the growth of mass media and the then current communication research designs employed to study the mass media influenced the approach used by educational media researchers. Because of this, media comparison studies grew in popularity (Rogers, 1986).

Media comparison studies were the primary focus of most research on media in education from the 1920s through the 1960s. Yet during this period, many researchers found problems in the nature of media comparison studies. Problems included faulty theoretical assumptions, deficient experimental designs, and lack of consistently significant findings.

The National Defense Education Act of 1958 caused a surge in media research during the late 1950s and 1960s. At the on-set of this time period, there was dissatisfaction with the research designs being used and the research questions being asked. It was pointed out by Knowlton (1964) that much of the media research to that date was based on faulty assumptions. Knowlton stated that assuming the key variable to be the means of information transmission rather than some aspect of the message, content, or the learner, would lead to false or contradictory conclusions.

Salomon (1981) reported that early media research has asked the wrong questions which were based on faulty assumptions. Salomon cited three faulty assumptions underlying research:
1. Each medium is an entity with fixed attributes. Studies of differential effects of media were expected to lead to better practical selection of one medium over another.

2. Media's entities were assumed to be alternative routes to fixed educational ends. Studies were to identify "better" media for teaching various disciplines.

3. Research findings were immediately applicable to solutions of problems encountered by educators.

In response to these assumptions, Salomon reported that:

1. The characteristics of a medium affects the modes of interaction with users and the transmitted content affects the knowledge acquired; thus, different aspects of media interact with different aspects of behavior.

2. The effectiveness of a medium depends on the nature of the instruction and the learner's characteristics. (A conclusion found in the Chicago film studies in 1924).

3. Theories often are not and do not meet the expectations of practitioners.

Commonly, many research reviewers have stated that researchers asked inappropriate questions and described this as a major problem with early media research (Hartley (1966); Knowlton (1964); Lumsdaine (1963); Salomon (1981)). According to Salomon and Clark (1977) the original research question (which medium most effects learning?) was invalid, leading to uninterpretable results. Clark (1985) stated that media comparison research, which indicated enhancements to learning occurred because of media, was confounded. More specifically, Clark stated that methodologically, a comparison between two media required an experiment in which all variables, except the media variable, were held constant. This being the case, any significant differences that occurred would be attributed to the presentation device. But in typical media comparison studies, other variables were seldom held constant and even then, significant differences were rarely found. And if found, the differences were often misinterpreted. It has been pointed out that educational media research was designed to measure the influence of technology upon academic achievement, rather than determine the real difference between the media themselves.

The most outstanding shortcoming of media comparison studies, as cited by researchers, was the results they yielded. Nearly sixty years of media comparison studies produced tenuous results. Most commonly, those studies that compared the relative achievement of groups receiving instruction from different media resulted in "no significant difference" of achievement between the groups (Clark & Surgrue, 1988).

When a new medium is introduced into the classroom, media comparison studies are conducted to measure its effectiveness in facilitating learning as compared with other media or with conventional instruction. Evaluation research is probably necessary to determine the impact a medium has; however, comparison studies are generally unnecessary. The literature clearly demonstrates that for every study that shows the new medium is better, another study shows the opposite. For example, Hartley (1966) examined 112 studies that compared programmed instruction with conventional instruction and found that on measures of achievement 41 showed programmed instruction superior, 6 showed programmed instruction significantly worse, and 37 showed no significant difference between the two treatments.

As a result of the critical reviews of early media research designs, research studies of the 1960s began to take on a new emphasis. The major emphasis shifted from the media themselves to media attributes. Media attributes research identifies and examines interactions among student, task, and specific media characteristics in terms of what happens when these variables are manipulated.

Intra-Medium Studies

Given the call from Clark and others to focus media research on more specific independent variables than just the medium itself, a number of researchers have designed studies that compare alternate methods of using a particular medium. The design of these studies are based on Salomon's observation that the effectiveness of a medium depends on the nature of the instruction (Salomon, 1981).
The major research question addressed in these studies is not "Which media is more effective?", but instead, "Which are the most effective instructional approaches using this medium?" Thus, in intra-medium studies, researchers might compare three instructional approaches to teaching Logo with microcomputers, or researchers might compare collaborative writing with individual writing using the computer. In these studies, a particular medium is used in all groups; the independent variable is the instructional approach, not the medium itself.

A recent study of computer based learning used to teach problem solving illustrates the intra-medium approach (Lehrer, 1987). In this study, Lehrer compared the effectiveness of three different computer based instructional approaches for teaching problem solving. In the study, forty five third graders were randomly assigned to instructional treatments. Therefore, the one independent variable being examined was the instructional treatment and its effect on student acquisition of problem solving skills. Lehrer's study and additional studies using the intra-medium approach are reviewed later in this paper. The intra-medium research design is gaining popularity in media research and results from these studies offer valuable insights to educators designing instruction.

Although intra-medium studies help provide necessary and useful focus for studies on the effectiveness of educational technology, many of these studies do not consider specific student aptitudes in their design. Including these aptitudes would certainly increase the value of the results of these studies.

Aptitude Treatment Interaction Studies

The critical reviews of media comparison studies produced a number of changes in how research was conducted. The reviews, coupled with transitions in educational psychology, resulted in a dramatic paradigm shift in media research. In the early 1970s, research on learning in education began to move from a behaviorist theory base to a cognitive one (Clark & Salomon, 1986). Within the new cognitive paradigm, learning was defined as "the degree to which previously learned knowledge and skills can be transferred to new contexts and problems" (Clark & Surgrue, 1988, p. 20). In other words, cognitive theory defines learning as a process in which the learner is actively engaged in integrating new knowledge with old knowledge. Student characteristics such as general ability, prior knowledge, motivation, and instructional methods are considered to be factors that influence whether or not learning from instruction occurs. (Clark & Surgrue, 1988).

This new cognitive paradigm was accepted by media researchers. They acknowledged the interaction that occurs between external stimuli (presented by media) and internal cognitive processes that support learning (Clark & Surgrue, 1988). Research that examines these types of interactions are commonly known as aptitude treatment interaction (ATI) studies.

Aptitude can be defined as any characteristic of a person that forecasts his/her probability of success under a given treatment (Cronbach & Snow, 1977). Moreover, an aptitude variable can be any characteristic upon which individuals differ. A treatment, as defined by Parkhurst (1975), is "any instructional strategy or combination of instructional strategies that structures information for the purpose of having students learn that information" (p. 42). Therefore, an aptitude treatment interaction exists when, as a result of a particular treatment, individuals at one end of an aptitude variable perform at one level on a criterion measure, and individuals at the opposite end of an aptitude variable perform at a significantly different level on the criterion measure.

Figures 5 and 6 illustrate an aptitude treatment interaction. In the diagram, the criterion measure is represented vertically with a scale of 0-100, and the aptitude variable is represented horizontally with a low-high continuum. T1 represents one treatment and T2 represents a second treatment. Thus, T1 would be the most appropriate treatment for individuals who rate high on the aptitude variable; and T2 would be the most appropriate treatment for individuals who rate low on the aptitude variable (Parkhurst, 1975). For example, hypothetical members of a ninth grade social studies class might need to learn the major events leading to World War II for an examination (the criterion measure, measured on a scale of 0 - 100). One student in the class, Latisha has a low verbal processing ability (the aptitude level, measured as high to low) and Keisha has a high verbal processing ability. Thus, a film covering the major events leading to World War II (T1) would be best for Latisha, and a series of newspaper articles (T2) would be best for Keisha.

In setting a foundation for new directions in media research, Cronbach and Snow (1977) stated that information about the learner is helpful in adapting instruction to him/her in order to provide an environment in which she/he
can thrive. "It is inconsistent to suppose that there is a single, global learning ability. The skills and habits that make a person a superior learner no doubt depend on the task, the methods of instruction, the conditions of practice, and the criterion against which learning is judged" (p. 13). Although adaptation to the individual has been a reoccurring slogan in education, such adaptation has never been systematic because the principles to govern the matching of learner and instructional environment have never been established; thus, research in this area is needed. The task for education researchers, according to Cronbach and Snow, is "to design a true education that employs unique means wherever the learner's distinctive development makes traditional methods ineffective for him/her" (p. 11). The study of interactions that occur between the learner and variables of instruction in order to facilitate the adaptation of instruction to the individual is the ultimate goal of aptitude treatment interaction studies; and therefore, such studies focus attention on whether or not a specific instructional method tends to facilitate or inhibit learning for individuals with particular aptitudes.

The examination of media attributes (as part of the instructional method) and media's influence on the way that information is processed in learning is a component of the aptitude treatment interaction approach. Clark and Surgrue (1988) have suggested that media may be understood more accurately by specifying media in terms of attributes, defining these attributes in terms which relate to the ways in which information is processed internally, and discovering relationships between these attributes and other important instructional variables. More pointedly, media attribute studies examine how specific elements of an instructional message might activate particular cognitions for certain learners under specific conditions (Clark & Surgrue, 1988). In such studies, cognitive processing is examined as a dependent variable, content treatments as independent variables, and learner characteristics as non-manipulatable independent variables. That is, instructional content is manipulated or treated in various ways in order to examine its differential effects on cognitive outcomes for different types of learners, and although learner characteristics are not variables that can be manipulated, it is assumed that learners affect the way they experience instructional stimuli and impact their own cognitive processing. For example, Cooper and Gaeth (1967) reported interactions between the instructional variable of the method of presenting mediated material and several learner aptitudes such as IQ, reading ability, and age.

Examining the roles and effects of media attributes in ATI studies has been a focus for many educational media researchers. Clark and Surgrue (1988) stated that media in and of themselves do not affect learning; rather, it may be certain qualities of media that may affect particular cognitive processes that are relevant for students with specific aptitudes to learn particular knowledge or skills. Plainly stated, the ability of a video camera, for example, to zoom in on an element within a subject may affect the ability of a student who has difficulty focusing on the relevant element of a subject, to learn the subject. Thus, the goal of media attribute studies has been twofold; researchers have attempted to identify critical attributes of media that distinguish media in meaningful ways and also affect the learning of relevant cognitions.

Early studies that examined media attributes sometimes referred to such attributes as symbol systems or symbolic elements of instruction. According to Clark and Surgrue (1988), endeavors to distinguish media in meaningful ways have resulted in clearer distinctions between ways of delivering and manipulating information. This information has contributed a great deal to systems and communication theories. For example, categorizations of media were established according to media qualities and characteristics. Such categories included projected media, non-projected media, motion media, still media, print media, and visual media.

The assumption that media attributes are independent variables that may affect learning was partially based on the premise that media attributes are unique and exclusive to each specific medium. Yet, Salomon (1974) claimed that attributes were merely correlated with media. That is, any one media attribute could be available from more than one medium. And, because media attributes are not exclusive to any specific medium, they are not media variables. Instead, media are vehicles for attributes. Clark and Surgrue (1988), have stated that "media are best conceptualized as delivery vehicles for instruction and not as variables that directly influence learning. Although certain elements of different media, such as animated motion or zooming, might serve as sufficient conditions to facilitate the learning of students who lack the skills being modeled, symbolic elements such as zooming are not media and merely allow us to create sufficient conditions to teach particular cognitive skills" (p. 29).

Clark and Surgrue (1988) perceived the change in the media research paradigm as one from a unidirectional view to a reciprocal view. According to Clark and Surgrue (1988), the cognitive paradigm assumes that instructional powers do not reside solely in the media, because the way learners perceive media influences what they learn. However, learners too, do not possess all instructional power because their perceptions are based on the kinds of
information and instructional methods presented by media. Aptitude treatment interaction research is concerned with the way different modes of the presentation of information are processed by the learner and how these processing capabilities develop. That is, these studies are concerned with the manipulation of the content using various methods of presentation, and the interactions of these presentation methods with learner variables. Collectively, the results of many such studies have yielded important implications for education. For example, Anderson and Lorch (1983) conducted a study on the design of television programs for children. They found that children attended to televised material that was comprehensible to them, implying that comprehensibility determined attention. This suggested that instructional design techniques used in the production of children's television programming should first be aimed at comprehensibility and then at attracting attention. Results such as this have contributed to the refinement of the systems approach and instructional design models.

With the increased popularity of cognitive theory, media comparison studies, which assumed that the media alone influenced learning, became less pervasive. Instead, intra-medium and aptitude treatment interaction studies, that applied cognitive theory ideas, and that examined the way media attributes interacted with cognitive processes, began to direct educational technology research.

Based on the results of aptitude treatment interaction research studies, researchers began to recognize the importance of different learning styles and methods of processing information, as well as the various correlations that existed between learner variables and content treatments. Thus, the study and understanding of ATIs can facilitate the design of improved instructional systems.

Alternative Research Designs

Although the majority of research on media in education fall into the four previously mentioned categories of studies (evaluation, media comparison, intra-medium and aptitude treatment interaction research), there are other studies that do not fit these categories, which we will call alternative research studies.

Given the new approach to the study of media in education, researchers may want to conduct what are called "hypothesis-generating" studies. That is, in order to help understand how learners interact with the technology, it may be necessary to conduct research designed to help generate appropriate empirical research questions. Also, in order to gain a deeper understanding of empirical research findings, it may be appropriate to conduct studies designed to more closely explore instructional relationships, particularly those afforded by newer interactive media. These studies would not use traditional research paradigms, but rather, would use naturalistic research paradigms that examine, qualitatively, the interactions between learners and technology. Case studies and ethnographic studies are approaches for naturalistic research (Cunningham, 1986).

Naturalistic research, in many ways, can be considered the opposite of empirical research. Empirical research, based on scientific empiricism, seeks to explain the cause-and-effect of phenomena. For example, the effect of television instruction on learning. On the other hand, naturalistic research attempts to describe a phenomenon as it occurs in its natural setting in order to draw inferences that have explanatory value (Neuman, 1989). Naturalistic research looks for patterns and themes that suggest "plausible connections between phenomena" (Guba & Lincoln, 1982, p. 242).

The naturalistic approach to research has been cited by Neuman (1989) and Guba (1981) as a method of moving computer-based education (CBE) beyond findings that simply state the method as being effective, to "a deeper understanding of the factors underlying that effectiveness as they are operationalized in classroom settings" (Neuman, 1989, p. 40). In other words, naturalistic studies of actual classroom use of computers may provide CBE courseware designers with strategies to produce lessons that are more effective for a variety of learners. For example, Hativa (1988) employed naturalistic research methods in order to examine the differential effectiveness of computer-based instruction (CBI) in arithmetic for high achieving and low achieving students. Hativa observed Sigal, a 7 1/2 year old second grader in Israel. Sigal was selected to be observed because she was a "typical student" according to her teacher. Hativa began observing Sigal in February 1985, six months after she began to practice arithmetic with the CAI system. Observations continued through June of 1985. During the four month period, Hativa's observations of Sigal consisted of the following:

• Sitting next to Sigal in the computer lab during her arithmetic computer sessions. During these sessions, descriptions of her behavior were recorded on paper.
• Every activity that took place on the computer was recorded, including each screen of each exercise, her answers, and computer responses.

• Interviews with Sigal immediately following each arithmetic computer session.

• Interviews with Sigal's parents in their home.

• Interviews with Sigal's teacher.

• Intervening tutorial work.

Data summaries led the researchers to conclude that it was not enough for an individualized system to provide each student with tailored exercises and immediate feedback. Instead, the behavior of the computer toward the student must also be individualized.

In another study, Neuman (1989) conducted an inquiry that explored the experiences of teachers and students with various kinds of CBI courseware. The findings about teachers' perceptions and behaviors described strategies for introducing and integrating CBI into classroom instruction and for intervening in students' CBI experience. The study found that students generally were unable to understand the errors they had made. To alleviate this problem, extensive teacher involvement was necessary. The study also found that teachers made few attempts to integrate CBI into classroom instruction in systematic ways which had implications for the integration of systems theory into the school.

The nature and extent of observed instructional involvement in CBI by teachers led to a number of suggestions for designing courseware that could increase students' independence at the computer. Among these are "simpler directions, perhaps graphically based or animated; on-screen suggestions for strategies for getting answers, perhaps available to students upon request; and feedback that explains the reasons for students' mistakes and suggests alternatives for arriving at correct responses" (p. 164).

Summary and Conclusion

As educational research has evolved, a two-part shift has occurred. Initially, research on media in education followed a purely behaviorist approach. This approach was evidenced by traditional evaluation and media comparison designs. Changes in part of the theory base of educational technology brought about the first transition in media research which was a shift from behaviorist theory to a cognitive approach. This transition resulted in a research design shift from the study of effects and media comparisons to the study of intra-medium studies and aptitude treatment interaction studies.

The second shift or alteration was the shift from empirical research to the inclusion of naturalistic research. Empirical or quantitative research seeks to explain the cause-and-effect of phenomena in order to make generalizations. Naturalistic or qualitative research focuses on a more narrowly defined population in order to describe phenomena. It is believed that a naturalistic research approach will assist in producing information that will influence the design of instruction to match individual needs. Certainly, the two forms of research are compatible since naturalistic research can be used to generate hypotheses for empirical research.

In this section, we have attempted to provide a review of the categories of educational technology. In so doing, we have organized research studies according to the research designs used. This was done in order to facilitate an understanding of the kinds of research results produced by these designs. It should be noted that the designs are not mutually exclusive, and that some overlap occurs.

Today, most believe that promising research areas in technology include:

• Research in hypermedia.

• Technology-supported problem-solving environments.
• Restructuring of schools through technology.

• Computer-based learning.

RESEARCH REVIEWS:
AUDIO, STILL PICTURES, FILM, VIDEO, COMPUTER-BASED LEARNING AND HYPERMEDIA

Introduction

In this section, relevant research in each of the major areas of educational technology will be reviewed. Research on audio, still pictures, video, film, computer based learning and hypermedia will be included in separate sub-sections. Although each technology will be considered separately, it is important to note that current uses of technology in education emphasize combining technologies to create learning environments for students, and that findings from each research sub-section relate to findings reported in the other sub-sections.

The tendency for educators to equate computer based learning to technology has already been noted in this paper. The computer has focused increased attention on educational technology, but should not be viewed as the only technology influencing learning today. The computer is usually the device facilitating the combination of technologies and often this combination is in a hypermedia format. Thus, work in the area of hypermedia must incorporate the findings on all the technologies reviewed in this section.

Research on Audio

INTRODUCTION

Of all the instructional media, current research on audio instruction is the least pervasive (Wilkinson, 1980). The majority of the studies conducted on audio instruction were done during the 1930s and 1940s when radio was the most common form of audio instruction available (Jamison & McAnany, 1978). Radio, the oldest electronic medium, began its role as a vehicle of instruction in 1919 with the establishment of station 9XM at the University of Wisconsin (Sandler, 1967). In an effort to examine the unique educational advantages of radio, Woelfel and Tyler (1945) found that "like other media, under certain circumstances and conditions radio can and does help in the achievement of widely different objectives" (p.39). This section will review research studies on the uses of audio as a stand-alone instructional medium, audio in conjunction with other media, and the effects of speech compression on learning. Recommendations from the research for effective production and use of audio in instruction will also be included.

RESEARCH ON AUDIO AS A STAND ALONE INSTRUCTIONAL MEDIUM

Much of the research conducted on audio tape instruction has been based on instructional radio research studies which were typically media comparison studies. In their review of radio in schools, Woelfel and Tyler (1945) cited a study conducted by Cohen in 1937 aimed at comparing the effectiveness of silent reading versus radio listening on the ability of elementary students' recall of facts. The results of the study yielded no significant difference between the reading and listening groups. The most significant finding from the study was that the radio listening group did equally well as compared to the standard reading group. This result suggested that people can learn from radio.

Woelfel and Tyler (1945) reviewed several research studies that were designed to compare the effectiveness of instructional radio with traditional methods of instruction. As Clark (1983) would have inferred, no significant difference in achievement resulted from the majority of the studies reviewed. That is, delivering instruction via radio or another medium was not the variable affecting student achievement.

As instructional media have evolved, various forms of audio technology have emerged. These include audio tapes (cassette, cartridge, and reel to reel), audio records, and audiodisks. The most common and economical audio storage device used in instruction is the audio cassette tape. Audio cassette tapes are considered to be the most economical because their initial cost is relatively low and they can be erased and reused many times.
Many audio tape studies have yielded similar results as radio studies. Following the research designs of the 1950s and 1960s, most studies conducted on the use of tape recordings in the classroom were media comparison experiments. Like comparison studies conducted with other media, the results of audio tape comparisons generally produced results that were not significant (Wilkinson, 1980). Popham (1961) conducted a study to test the effectiveness of using tape recorded lectures versus live lectures in teaching a college course. Popham reported no significant difference in student achievement; however, he cited that the results may have been attributed to the kind of material taught and that with different course content and learning objectives audio tape might be either more or less effective. It could be generalized from this study as from other media comparison studies, that the effect on learning is not produced by the medium alone. Rather, many factors such as learner motivation and instructional method influence learning.

The use of audio tapes in foreign language classes has been an important use of this medium. In one study, Lorge (1963) reported that the use of language laboratories could increase student performance in foreign language classes. In his study with high school students, Lorge compared students who used the language laboratory a minimum of twice a week for at least twenty minutes to students who did not use the language laboratory. The results indicated that those students who used the language laboratory were superior in foreign language speech fluency, intonation, and comprehension (at slow and fast speeds) as compared to those who did not use the laboratory.

Recent research on the use of audio instruction has primarily been in the areas of self-paced or individualized instruction and audio tutorial instruction (Postlethwaite, 1969). Most of these studies employed aptitude treatment interaction designs because they attempted to explore the interactions between specific instructional materials and individual learners. For example, Kroll (1974) explored the relative effectiveness of written and individualized instruction in the intermediate grades. In his study, Kroll examined the interactions of high and low ability readers and the acquisition of information through listening. Kroll hypothesized that listening to audio tapes by low ability readers would capitalize on their existing capabilities of being able to listen well, thus they would achieve at the same levels that high ability readers do with written material. The results of the study indicated that high ability readers learned as much from reading as they did from listening; and that low ability readers learned as little from reading as they did from listening. In other words, poor readers were not superior or even equivalent listeners in terms of learning, as were their superior reading counterparts.

Mintzes (1975) reviewed several studies using audio taped instruction in college science courses. He stated that consistent evidence about the relationships between student aptitudes and achievement in audio tape courses was limited. However, from the fourteen years of audio tape studies he reviewed, he was able to make two generalizations: strong backgrounds or aptitudes in science, biology, and mathematics contribute to achievement in biology courses that used audio tapes; and variables such as college major, high school grades, and college grade point average appeared to be predictive of achievement. At times these generally were not related to the use of audio.

The results of these studies indicate that:

• Students can learn from audio as a stand alone instructional medium.

• The use of audio tapes can be effective in foreign language laboratories.

• Listening skills, like reading skills, must be taught and developed in order for audio taped instruction to be effective.

• The effectiveness of audio taped instruction is contingent on many variables such as student ability and nature of the instructional material.

AUDIO IN CONJUNCTION WITH OTHER MEDIA

Some form of audio often accompanies other media in the delivery of instructional material. Such forms of audio include music, sound effects, and narration. The effects on learning of various audio forms have been the focus of many research studies. For example, Raburn and Tyson (1982) examined the effects of background music on
lecture tapes, filmstrips, and films used in teaching college psychology. One intention of the study was to compare the learning effects of background music on men and women and visual learners and non-visual learners.

Raburn and Tyson found that all of the combinations of media (lecture tapes with music, and lecture tapes alone, filmstrips and audio, filmstrips alone, films and audio, and films alone) were effective. However in this study, film and audio were superior for women, and film with audio and lecture tape with music were favored. The results also indicated that visual and non-visual learners varied in their response to background music with lecture tapes, however, both groups raised achievement scores when background music was added to lecture tapes.

Within the area of special education the use of background music may have significant implications. Mahler (1978) reported that "background music is a powerful medium which can accentuate or maintain overt behaviors in response to conscious sensory stimuli" (p. 3). Mahler stated that the use of background music could increase the effectiveness and efficiency of the instructional process in special education. He attributed the possible gains facilitated by the use of background music to research findings in left and right brain functioning.

Raburn (1980) examined the effects of background music in helping lower socioeconomic American Indians understand films. The results of the study indicated that sound, even in the form of background music or sound effects, appeared to be essential to the understanding of films.

The research reviewed and similar studies conducted in the area of audio when it was used to accompany other forms of media have suggested the following:

• Students can learn when various forms of audio accompany other media.

• The use of background music can increase achievement for some learners, but is probably not necessary.

• The use of audio with other media may enhance the understanding of content material.

• The meaning of a visual message is often ambiguous and subject to personal interpretation. The use of words to direct attention is essential.

• With visuals, some verbalization is better than none, but there is no optimum amount. Slow speeds for transmitting verbal information are favored but they can be too slow. Rate needs to be tailored to fit the student and their familiarity with the content.

• When narration is accompanied by video, the optimum rate of the narration appears to be slower.

• The audio channel is much more capable of obtaining attention if it is used as an interjection on the visual channel rather than being continuously parallel with the visual.

THE EFFECTS OF SPEECH COMPRESSION ON LEARNING

A high percentage of instructional material in education is presented aurally. When these instructional methods are employed, students must listen and take in information at a pace or rate set by the lecturer, which may not be the most appropriate rate for the student. The lecturer's rate may be too fast for low aptitude students or too slow for high aptitude students; or the rate may be inappropriate for the degree of difficulty of the material. That is, it may be to slow for easy to understand content or too fast for more demanding content.

The average classroom instructor lectures at a rate of about 100 words per minute (wpm) while the average speed of thought for college students is approximately 400 to 800 wpm (Short, 1977). Short stated that "this discrepancy between speech rate and comprehension rate may cause the student to become bored and inattentive." (p.147) Rate controlled speech compressors may be used to solve this problem. A rate controlled speech compressor is a modified tape recorder that facilitates the reproduction of speech in more time or less time than was required for original production. Time compression of speech refers to the process of increasing the rate of speed at which an audio tape is played back. It is the process whereby the amount of time to playback an audio tape is less than the originally recorded time required for playback.
Many researchers have examined the effects of time compressed speech on learning. For example, Short (1977) conducted a study to determine whether college students in a basic nutrition course using self-instructional methods learned more and saved time learning through the use of rate controlled speech compressors and audio tapes, as compared with students who used tapes played at regular speeds.

Short found that students who used speech compressors achieved significantly higher scores than those students who did not use speech compressors. Short's study also indicated that students using speech compression devices saved an average of thirty percent more time than students who listened to tapes at regular speeds.

King & Behnke (1989) conducted a study to investigate the effects of varying levels of time compressed speech on comprehensive, interpretive, and short-term listening. The results from the study indicated that comprehensive listening performance decreases significantly as the rate of speech compression increases. He also found that interpretive and short-term listening performance remain stable until high degrees of speech compression are reached.

From these studies and others on speech compression, it can be concluded that:

• The use of rate controlled speech compression tape recorders can enhance the achievement levels of high and low aptitude students on aurally presented material.

• Speech compression can enhance achievement.

• High rates of speech compression may not be appropriate for certain kinds of listening requirements.

• The rate of speech compression must be set according to variables such as general ability, familiarity with the subject, and level of difficulty of material.

SUMMARY AND CONCLUSION

Because of the scarcity of research on audio instruction, there is little information about how to produce effective audio tapes. According to Allen (1974) "the most applicable of design principles to audio production are those involving attention-directing techniques, repetition, and content pacing" (p.86). Allen stated that repetition of important concepts has proven effective. The following is a list of research-based audio production techniques compiled from Kemp (1975) and others (Hartman, 1961a, 1961b; Hoban & Ormer, 1950):

• The use of simplified verbal terminology increases teaching effectiveness.

• Comprehension of audio can be predicted by readability formulas to measure their difficulty.

• Listening comprehension is likely to be most effective at speeds of 160 words per minute. (This is true for relatively simple material, and the intellectual level of the audience must be taken in to consideration.)

• The meaning of a visual message is often ambiguous and subject to personal interpretation. The use of words to direct attention is essential.

• With visuals, some verbalization is better than none, but there is no optimum amount. Slow speeds for transmitting verbal information are favored but they can be too slow. Rate needs to be tailored to fit the student and their familiarity with the content.

• When narration is accompanied by video, the optimum rate of the narration appears to be slower.

• The audio channel is much more capable of obtaining attention if it is used as an interjection on the visual channel rather than being continuously parallel with the visual.
Research on Still Pictures

INTRODUCTION

A still picture can be defined as a drawing, painting, portrait, or photograph. The effects on learning of still pictures have been the subject of many studies. Researchers in this area have examined the impact of different visual elements (such as color and degree of reality) on learning and retention. Studies have also been conducted to evaluate and compare the two forms of still visual images: projected (slides, filmstrips, and overhead transparencies), and non-projected (photographs, study prints, and charts, etc.) (Wilkinson, 1980). This section will define and discuss still pictures in education and review research studies that have examined aspects of visual illustration and motion media versus various forms of still pictures.

DEFINITION AND BACKGROUND

A visual is anything that is perceived through the eye. A still picture is a type of visual; more specifically, a still picture is a drawing, painting, portrait, or photograph (Funk & Wagnall, 1968). The primary purpose of a still picture in education is to communicate. That is, typically a still picture is used to visually provide information, and often, to reinforce verbal information. A picture is composed of elements of design. The design elements that make up a picture include line, shape, texture, space, and color.

Principles of design provide an organizational structure within which to create visuals that communicate; they provide guidelines for putting together design elements (Nelson, 1984). These principles are based on communication theory and include the following:

Balance refers to the weight of the design elements on a page. That is, the design elements are arranged on a page in such a way that if the page were cut in half, both sides of the page would be perceived as being even. In symmetrical balance both sides of a page contain the same number of elements that are the same size. In asymmetrical balance the elements of both sides of a page are not the same; however, the elements are placed on the page in such a way as to create an equilibrium and a sense of balance.

Unity denotes creating a relationship between the elements of a visual. This should be done so that all the design elements are perceived as functioning together.

Emphasis infers that the most important concept to be communicated is placed in such a way that it is viewed as the center of interest and attention. (Kemp & Dayton, 1985)

Illustrations can be defined as pictures, diagrams, or maps, used to explain an idea or concept. The objective of pictures, and illustrations, in education is to communicate in order to facilitate learning. Visual illustrations can represent different levels of reality. That is, still pictures can be defined by the degree of reality they represent.

VISUAL ILLUSTRATION: ABSTRACT VS. REALISTIC

Many studies have been conducted to measure the effects on recall of pictures and pictures with verbal information. Many of these studies were evaluations designed to examine whether or not students could learn and recall information presented by visuals; and comparisons, comparing the effects on learning, recognition, and recall of different visual elements of two or more media. Cody (1982) conducted a study to investigate the effects of symbolically formatted test material on short- and long-term recognition. In his study, college students viewed a series of 57 slides. Each series had four slides of the following: a black and white photograph of an image, one-sentence description of the photographed image, black and white line drawing of the photographed image, and black and white drawings of the description of the photographed image. After viewing the slides, students were immediately given a recognition test. A second test was given two days later. Cody found that the most important
factor affecting retention was the type of feature encoded and not the number of ways that the feature was encoded. Moreover, he stated that retention was partially attributed to the characteristics of the visual cues encoded. He also found that the photographs directly assessed semantic information. That is, photographs can be used to represent written or verbal information in order to facilitate recall. Additional details like color and a high degree of realism are not necessary for recognition.

The degree of reality needed in order for learning to occur has been an important category of still visual research. That is, many researchers have examined a continuum of reality to discover if the degree of reality of an image effects learning and recall and if so, what levels of realism effect what kinds of learning. Dwyer (1968, 1970) has conducted a number of studies examining the interactions between reality and learning. In one study, Dwyer, (1968) varied the amount of realistic detail in illustrations designed for programmed instruction. In this study it was assumed that students would interact with illustrations and this interaction would facilitate learning. The experimental groups viewed verbal descriptions, black and white abstract line illustrations, more detailed drawings, and realistic photographs. The control groups received only verbal descriptions. After testing to measure the learning that had occurred under the various conditions, Dwyer found that students did not know how to learn from drawings and photographs and that a continuum of visual illustrations extending from abstract to realistic representations is not an effective predictor of learning. This study also confirmed results from earlier studies (1968) in which Dwyer concluded that for specific objects and for students in certain grade levels, color appeared to be an important instructional variable for improving student achievement. Generally, however, color was not necessary for learning, unless the objective of the lesson involved color recognition.

In 1979, Joseph conducted a study to examine whether the integration of abstract and realistic visuals with text can improve the effectiveness of instruction or instructional segments. He concluded that the effectiveness of visually-based instruction could be enhanced by including realistic visuals with abstract ones; however, the integration of abstract and realistic visuals should be based on many considerations, such as general ability of the learner, instructional objectives, and pacing of the instruction. In a follow up study, Joseph and Dwyer (1982) arrived at similar conclusions. They concluded that integrating realistic and abstract visuals may reduce achievement differences between students with varying abilities.

Wise (1982) and other researchers (Dwyer, 1970; 1968; 1967) who have investigated learning and degrees of reality represented by still visual images, have concluded that simple line drawings are superior to realistic photographs in facilitating the interpretation of stimuli. They have also found that other elements increasing the level of reality, such as color, do not significantly enhance learning unless the instructional objective requires that such elements are learned. For example, an instructional objective requiring students to identify the parts of a flower may not require color. However, an instructional objective requiring students to identify several different kinds of flowers may require color as one distinct characteristic of flowers. Dwyer has concluded that the addition of unnecessary visual elements can distract students from identifying and focusing on relevant cues (1970). He defined relevant cues as those elements of a visual that are needed for students to achieve the instructional objectives.

STILL PICTURES COMPARED WITH OTHER FORMS OF MEDIA

Several studies have been reported in the literature that have tested the effectiveness of still pictures as compared with other forms of media. These studies were conducted under a variety of learning conditions and instructional objectives. In particular, a few sought to measure the effectiveness of different forms of still pictures.

Wilkinson (1980) cited a 1961 study by Kelly who examined the use of filmstrips to teach reading. In the study, he compared two groups of first graders. The experimental group students were taught to read using filmstrips and the control group was taught by traditional methods. From the study, Kelly found that when tested with the Gates Primary Reading Test, the experimental group did significantly better in word recognition and sentence reading than the control group.

In a media comparison study, Chance (1960) compared use of transparencies incorporated into regular lecture and discussion formats of a college geometry class with the regular lecture and discussion. He found that the groups using the transparencies did significantly better on the final examinations than the groups receiving just lecture and discussion. He also found that the use of transparencies resulted in a saving of 15 minutes of instruction time per class period.
New approaches to teaching in the 1960s have stressed the development of independent study. Many researchers have attempted to address this issue of independent study. They have endeavored to devise methods for developing flexible instructional materials that could be presented in a variety of ways. In so doing, researchers thought it was necessary to discover which media under what conditions were most effective for presenting specific concepts (Lumsdaine, 1962). For example, Wells, and others (1973), conducted a study designed to examine the effects of different visual media in teaching different visual concepts. More specifically, the study examined sequential still photographs, slides, and motion pictures which were used to present the visual concepts of time, space, and motion. The study was conducted in a general biology class where three groups received three different visual treatments. Wells found that motion pictures were superior to both sequential photographs and slides in presenting the concept of time. It was concluded that the visual concept of time was best presented by media that allowed the viewer to perceive a continuous presentation. The results also indicated that motion pictures were more effective for presenting concepts involving motion than were sequential still photographs. And slides were superior for presenting motion than sequential still photographs; however, there was no significant difference between motion pictures and slides in presenting motion as determined by scores on the post-test. Last, the study indicated that sequential still photographs and slides appeared more effective than motion pictures in presenting concepts involving space.

In 1966, Otto, conducted a follow-up study examining the difference in student responses to information coded using black and white drawings and verbal descriptions of the drawings. The results of the study confirmed those of earlier studies. Otto found that "verbal representation evoke more sensory response than do black and white line drawings of the same information". This indicated that verbal descriptions were considered more effective than black and white line drawings in facilitating learning in this situation.

SUMMARY AND CONCLUSION

The results of these studies, and others conducted by Dwyer, indicated the following:

- The effectiveness of a particular visual in facilitating student achievement of a specific objective depends on the type of information needed by the student to achieve that objective.

- For some very specific objectives, the addition of color may improve student achievement.

- Additional details like color and degree of realism are not needed for recognition.

- For students in different grade levels, the same visuals are not equally effective in increasing student achievement of identical objectives.

- The effectiveness of visually-based instruction may be enhanced by including realistic visuals with abstract ones. This integration of abstract and realistic visuals should be based on general ability of the learner, instructional objectives, and pacing of the instruction.

- Integrating realistic and abstract visuals may reduce achievement differences between students with varying abilities.

- Photographs are effective in representing written or verbal information in order to facilitate recall.

- For some students, verbal descriptions can effect learning more than black and white line drawings.

- Motion media (such as video or film) are more effective in presenting the passage of time than sequential photographs and slides.

- In some instructional contexts, motion may effectively be presented by slides.

- Still photographs and slides may be more effective than motion pictures in presenting concepts involving space.

- The use of visuals to compliment oral or verbal instruction does not automatically improve student achievement.
Research on Films

INTRODUCTION

Research on instructional film began around the time of World War I with the largest number of studies reported in the mid 1950s. By the 1970s, the number of research studies dealing with the effects of film on learning had declined considerably; however, a number of studies that examined how individuals learn from film have been conducted since then. This section will include an overview of three major film research reviews and, more specifically, will review the research on film and its effects in imparting factual knowledge, the effects of film on higher cognitive learning, and the effects of film as related to learning styles.

MAJOR FILM RESEARCH REVIEWS

There are three major reviews of the research on films: Hoban & Ormer's review of instructional film research 1918-1950; U.S. Army World War II studies on the use of films for training; and the Reid and MacLennan review (1967). Each of these studies has contributed significantly to the body of knowledge on the effects of film on learning. The review of instructional film research 1918-1950 (Hoban & Ormer, 1950) is a comprehensive compilation of the research studies conducted from 1918 to 1950. Their specific intention for reviewing the research on film was to establish an initial guide for accurately predicting the results of instructional film as well as improve the production processes used to develop instructional films. The guidelines they recommend for the production and utilization of instructional film will be reviewed in the conclusion of this section.

Reid and MacLennan (1967) reviewed approximately 110 studies on instructional film from 1950-1964. Their review of film and television entitled "Research in Instructional Television and Film" could be considered a continuation of Hoban and Ormer's review. Reid and MacLennan also confirmed that instructional film research exhibited the same general no significant difference pattern as that reported previously. Reid and MacLennan also contributed to the development of a number of research based production and utilization recommendations. These are listed at the conclusion of this section.

In World War II, films were used extensively by the Army and Navy for training and morale purposes (Hoban & Ormer, 1950). During this time, three series of research studies were conducted. Two of the series were concerned with the effectiveness of films in bringing about specific learning outcomes and one of the series of studies focused on the organizational factors that influenced the use of films in instructional situations. The Army World War II studies provided a research foundation for instructional film. The extensive studies were mostly media comparison studies. They summarized the effectiveness of films as delivery systems, and "set the stage for a second phase of film research which discriminates to a greater degree the variables within films and their utilization which contribute to the effectiveness of motion pictures." (Hoban & Ormer, 1950, p. 2-5). In other words, the Army World War II film research studies alleviated the need for any further media comparison studies and provided a foundation for other research designs. Specific studies from the Army World War II research will be included in the following section.

THE EFFECTS OF FILM ON LEARNING FACTUAL INFORMATION

The attainment of complex learning objectives is based partially on a knowledge of facts (Hoban & Ormer, 1950). The effects of film on the acquisition of factual knowledge has been examined by many researchers. In three different studies reported in one paper (Hovland, Lumsdaine, & Sheffield, 1949; one of the Army World War II research studies), researchers examined the effects of the "Why we fight" military films. Designed to increase soldiers' knowledge about the events leading to World War II and the progress of the war, these films were found to
significantly increase the factual knowledge possessed by military personal. More specifically, Hovland, Lumsdaine, and Sheffield found that the factual learning from the "Why we fight" films depended a great deal on the educational level and intelligence of the audience.

Knowlton and Tilton (1929) conducted a study to examine the role of silent history films on the acquisition of historical facts. In this study which lasted one semester, the Yale Chronicles of America Photoplays (a series of plays recorded on film) were coupled with regular teaching materials and presented to an experimental group of seventh graders. The control group (of seventh graders, also) was taught with the regular teaching materials only. Knowlton and Tilton reported that the scores from the group instructed through the use of films and regular instruction exceeded the scores of those receiving regular instruction only.

In a follow up study, Wise (1939) also used the Yale Chronicles of America Photoplays in teaching history to eleventh grade students. Like the Knowlton and Tilton (1929) study, the experimental group was taught with the films and the regular instructional material, while the control group received instruction from regular instructional material only. Wise's findings confirmed those of Knowlton and Tilton. In order to test the groups, Wise used a standardized history test (Columbia Research Bureau's American History Test). Wise found that the group receiving regular instruction and film scored higher, and thus had learned more factual, general history knowledge, than those receiving instruction solely from regular instructional material.

The Knowlton and Tilton (1929) and Wise (1939) studies provided insight into the kinds of general knowledge that may be acquired from films depicting factual information. Additionally, studies have been conducted that have provided insight into the kinds of specific knowledge that can be gained from the use of films. Wise (1949), in a study of the enrichment effects of motion pictures when they were used in rural schools, found that for information tests related directly to the content of the films used, the film groups scored significantly higher than the non-film groups. The same was found to be true in a similar study conducted by Scott (1949). In his study, Scott examined the learning that occurred in high school science and social studies classes when films were used. Scott found that the influence of films tended to be specific to the areas covered by the content of the films. In other words, the scores of the regular instruction and film group was significantly greater than those receiving regular instruction on content specific tests. However, the difference in scores between the two groups was significantly less when standardized tests were used as measures of achievement.

From these studies it can be concluded that:

- Films can convey factual information. When the instructional objective is to impart factual information that can be presented visually, films can be an effective medium.

- The acquisition of facts varies depending on the audience. There are various learner characteristics that influence the acquisition of factual information by each individual.

- The contribution of films is specific. That is, the factual information gained through a film contributes more to a person's specific knowledge than to his/her general knowledge.

THE EFFECTS OF FILM ON HIGHER COGNITIVE SKILLS

Hoban and Ormer (1950) stated that "the principle value of a knowledge of facts lies in the ability of an individual to apply, or use, the facts." (p. 3-1) Therefore, it is not enough to just teach factual information. One purpose of education is to teach students higher order thinking skills such as hypothesis generating and problem-solving. The effects of film in the acquisition of higher cognitive skills has been the focus of several research studies. Rulon (1933), in an effort to investigate the influence of films on "rote" and "educative" learning, conducted a study using ninth graders in a general science class. In his study, rote learning was measured on tests by rote items or those requiring recognition of facts only. Educative learning was measured by educative items which required the application of concepts. Over the six week research period, the experimental group learned general science content with both textbook and films, and the control group was taught with just the general science textbook.

Rulon found that students taught by text and film scored higher on the educative test items than did the text only group. The text plus film group also scored higher on rote test items than did the text only group. There was a greater difference between the two groups' scores on the educative test items than rote test items. Concerning that
difference, however, Rulon stated that performance on eductive items can be predicted more accurately from specific learner characteristics, such as previous achievement in general science, than from scores on rote test items.

In a study that examined the teaching of inquiry skills to children, Suchman (1961) exposed fifty intermediate grade school students to various science problems via filmed demonstrations. The students were then taught inquiry, prediction, and projection skills by actually identifying objects in the filmed demonstrations, verifying conditions and changes in the objects, and citing variables responsible for changes in the objects.

To evaluate learning after inquiry training, students were measured by the types and numbers of questions they asked in problem-solving situations. Suchman reported the results of the study in terms of individual progress. Noting the wide range of difference, Suchman concluded that this type of training was beneficial in helping children increase inquiry skills. From this study, it can be concluded that inquiry skills can be taught through content presented by films.

A follow up of Suchman's (1961) study was conducted by Wright (1978). In this study, the same films used by Suchman were studied. After assignment to one of the three treatment groups, subjects were shown a film of a problem situation. They were then asked to list as many details about the problem situation as possible (a maximum of 75) and as many hypotheses as possible (a maximum of 5). More than a year later, the subjects viewed a new set of films of problem situations in order to test the long term retention of previous inquiry training. The study found that those students who had received intensive inquiry training using films were able to list a significantly higher number of details from a problem situation than those who had not received inquiry training.

It can be concluded from these studies that:

• Film can contribute significantly to the acquisition of eductive learning as well as rote learning.

• It is possible as a result of training by film for students to develop the abilities to attend to details and generate hypotheses in given problem situations.

• The development of higher order thinking skills in children, such as inquiry ability, can be facilitated by films.

RELATIONSHIP OF FILM TO LEARNING STYLES

About 1960 the approach to instructional film research began to shift. Like the shift in focus of other media research, film research studies began to concentrate on learner characteristics and their interactions with the content of films. A limited number of studies, however, have examined the interactions between films and learning styles. Three studies will be reviewed here in order to provide a basic understanding of how students learn from film.

In order to test if an interaction between cognitive style and behavior existed, Thomas (1972) conducted a study with 143 boys ages 5 to 8. In the experiment the boys were divided into three groups. The first group viewed a film exhibiting aggressive behavior. The second group viewed a film with nonaggressive behavior, and the third group did not view any films. After viewing the films, a test measuring for aggression revealed that: younger boys became more aggressive after watching aggression films than did older boys; and cognitive styles became more differentiated with age. That is, there was a relationship between learning style and age. The older boys' learning style was different from that of the younger boys.

Multiple studies conducted at Iowa State University (Simonson, 1987) examined interactions between media and learner aptitude when attitude change was the goal. More specifically, the studies examined learner characteristics such as field dependence, field independence, and hemisphericity as they interacted with mediated messages. The goal of the studies was to alter student attitudes toward soil conservation or disabled persons.

Two of the five studies conducted yielded results that indicated that an interaction existed between the treatment (method of mediation), cognitive style, and attitude change. It was found that field independent students who viewed the film on soil conservation had higher attitude scores than other treatment groups, and field independent students who viewed the film on disabled persons developed more positive attitudes toward the subject. Also, left brain dominant students had more positive attitudes towards soil conservation than right brain dominant students.
For this study, the researchers concluded that material presented by film was effective in changing the attitudes of a variety of learners, and particularly attitudes of field independent learners.

In a study conducted at Purdue University, Snow, Tiffin, and Seibert (1965) sought to investigate the interactions of learner characteristics such as responsibility, emotional stability, numerical and verbal aptitude, attitudes toward film and physics, and prior knowledge of physics. The results of the study that examined 437 college students indicated that students who were active, self-assured, and independent performed better academically with instruction via film than face-to-face instruction. Students who ranked low in responsibility and were less independent tended to prefer traditional instructional methods, and those students with low numerical and verbal aptitudes performed better after receiving instruction through films. From these results, the researchers speculated that viewing films clarified physics concepts for low aptitude students. The researchers concluded that the instructional method can facilitate learning for some students while inhibiting it for others.

From these studies on the effects of film on learning style, it can be stated that:

• Films may be more effective with field independent learners who are left brain dominant, rank high in responsibility, and are low in numerical and verbal aptitude.
• Face-to-face instruction may work better than instruction via film for passive, less responsible students with high numerical and verbal aptitudes.

SUMMARY AND CONCLUSIONS

From the three major research reviews on instructional film (U.S. Army World War II studies, Hoban and Van Ormer review of instructional films 1918-1950, and the Reid and MacLennan reviews of film) came several recommendations for the use of instructional films. The studies reviewed here have also resulted in conclusions indicating the benefits of film in education. From these studies, a list of the uses and benefits of instructional film has been compiled.

• Films can convey factual information. When the instructional objective is to impart factual information that can be presented visually, films can be an effective medium.
• The acquisition of facts presented by films varies depending on the audience. There are various learner characteristics that influence the acquisition of factual information by each individual when the facts are presented in films.
• The contribution of films is specific. That is, the factual information gained through a film contributes more to a person's specific knowledge base than to his/her general knowledge base.
• Films can contribute significantly to the acquisition of eductive learning as well as rote learning.
• It is possible, after training, for students to develop the abilities to attend to details and generate hypotheses in given problem situations depicted by films.
• The development of higher order thinking skills in children, such as inquiry, can be facilitated by films.
• Films may be more effective with field independent learners who are left brain dominant, rank high in responsibility, and tend to be low in numerical and verbal aptitude.
• Face-to-face instruction may work better than instruction via film for passive, less responsible students with high numerical and verbal aptitudes.
• Films may have the greatest impact when the content they present reinforces or extends the previous knowledge of the viewers.

Hoban and Ormer (1950) stated that the impact of instructional film on learning is contingent on several variables such as the content of the film, the way the content is treated, the psychological disposition of the audience, and the
context or situation in which the film is presented. Keeping these variables in mind, Hoban and Ormer have
developed guidelines from the research that indicate what makes a film instructionally effective.

• The influence of a motion picture is more specific than general; therefore, specific instructional objectives should
accompany an instructional film.

• The content of a film should be directly relevant to the response it is intended to evoke in the viewers. This
increases the influence of a film.

• The influence of a motion picture is relatively unaffected by fancy production techniques. Instead, a clear
meaning presented by good visuals and commentary are the primary considerations.

• Viewers respond to instructional films most efficiently when the visual content is presented from the perspective
of the learner.

Research on Television

INTRODUCTION

The teaching effectiveness of television has been well documented by over forty years of research. Summing up the
research on television, Chu and Schramm(1967) concluded that "given favorable conditions, children learn
efficiently from instructional television...the effectiveness of television has now been demonstrated in well over 100
experiments, and several hundred comparisons,... at every level from pre-school through adult education and with a
great variety of subject matters and method" (p. 1).

This section is divided into two parts. The first part will review the research on traditional, one-way instructional
television. The second part will review interactive two-way instructional television research. Both subsections will
summarize research findings and include recommendations.

ONE-WAY INSTRUCTIONAL TELEVISION

One-way instructional television can be defined as instruction via television that accommodates only one direction
of communication and interaction. That is, one-way instructional television allows the originator of instructional
information to communicate with viewers; however, it does not allow the viewers to interact with the instructor or
originator of instructional information. One-way instructional television is either broadcast live or played from a
prerecorded videotape. Broadcast programs are those whose content is aired by a station according to the station's
schedule. Broadcasting can be over the air, through a cable, or via a communication satellite. Videotaping of
live broadcast programs permits viewing those programs at times other than when they are originally aired

Research on one-way instructional television followed the same research design patterns as other media. Early
studies on the effects of instructional television on learning used media comparison designs; however, the results
were both evaluative and comparative in nature. That is, the results from research comparing television and other
media indicated that generally there was no significant difference in student achievement when instruction was
provided by television or other media (media comparison results). However, these studies indicated that given the
correct conditions, students learned from television (evaluation results). For example, Sykes (1964), studied 58
education majors who had been randomly assigned either to a television group or to a control group that received
instruction through traditional methods. The television group watched six 45-minute art lessons over six weeks,
while the control group did not view the art lessons. A post-test indicated that there was no significant difference in
student achievement between the control group and the group that viewed the art lessons on television. The results
indicated that students learned from television.

Schramm (1962) summed up 393 experimental comparisons of television vs. classroom teaching, including a
considerable amount of unpublished material. He reported that 255 of these comparisons showed no significant
differences in student achievement, 83 were significantly in favor of televised teaching, and 55 were significantly in
favor of conventional teaching.
As media research designs changed, so did the research questions and approaches employed to study the effects of one-way instructional television on learning. Chu and Schramm (1967) stated "The question is how to make effective use of television as an instrument of teaching" (p.22). Chu and Schramm (1967) reviewed several studies examining student aptitudes, instructional situations, and/or content treatment variables. One such study was conducted by Mullin (1956). It investigated the interaction between motivation and home or school viewing of instructional television programs. In the experiment, eleventh-grade students were divided into two groups called motivated and unmotivated. The motivated group had the promise of monetary reward; the unmotivated group received no such promise. Within each group, half of the students viewed instructional programs on explorations of space at home, and half viewed the same programs at school. Two tests were given to the groups, the first was given one day after the students viewed the programs, and the second test was given two weeks later. The results indicated that the motivated group scored significantly higher on both tests. However, the results also indicated that unmotivated viewers learned more in the classroom, and motivated viewers learned more at home.

The Mullin study (1956), and other similar studies that concentrated on the variables affecting the degree of success with which television could be used, produced documentation of the characteristics of successful programs, and provided guidance about the ideal conditions for learning from television. The following is a listing of characteristics and conditions of effective one-way instructional television as compiled by Chu and Schramm (1967) and Newman (1981).

**Characteristics of Effective One-way Instructional Television**

Significant gains in student achievement may result when one-way instructional television programs:

- Repeat the key concepts in a variety of ways.
- Make use of animation, novelty, variety, and simple visuals (for young children).
- Entertain as well as inform.
- Make use of a trained communicator in presenting information (for adults: make use of nationally known personalities).
- Provide opportunities for students to participate in a learning activity, either in response to information presented in a program or as part of a game presented by the program (for young children).
- Match the length of the program to the attention span of the intended audience.
- Follow principles of effective audiovisual presentations.

**Characteristics of Effective One-way Instructional Television Viewing**

Students show gains in achievement from viewing one-way instructional television when teachers:

- Prepare students to receive information presented by the television program.
- Provide reinforcing discussions and activities following viewing.
- Provide corrective feedback to students, based on what students reveal they have understood from the program, in follow-up discussions between students and teacher.
- Provide students with frequent feedback about their achievement as a result of viewing.
- Maintain sufficient contact with students during instruction via television (for college students).
- Assume an active role in the instruction that accompanies the viewing of television programs.
**Characteristics of Effective Planning for Teaching with One-way Instructional Television**

Planning for effective teaching with one-way instructional television includes:

- Selecting programs which accommodate the teacher's classroom management style.
- Selecting broadcast times which meet classroom needs or using videotapes of programs at times.
- Incorporating television as part of a coordinated instructional system, including use of a teacher presentation text, study guides, and tests of achievement gains.
- Using television programs when what is to be learned requires visualizing, and continuity of action.
- Using television when reducing student anxiety is a priority (capitalizing on the third person, non-judgmental nature of the medium and student familiarity with the technology).

The effectiveness of one-way instructional television has been substantiated by many studies. From the studies reviewed it can be concluded that television can provide instruction that might not otherwise be available. One-way instructional television, as a delivery system, can present material in a manner that facilitates learning. Methods for effectively incorporating the medium into instructional settings have been established and will continue to be explored as the technology continues to advance and become more commonplace in schools.

**TWO-WAY TELEVISION: DISTANCE EDUCATION**

Adults wanting to participate in formal education must deal with a variety of barriers including limited time to take classes, location of desired classes in relationship to home and work, and the costs of formal education (Cross, 1981). Young people located in sparsely populated areas face similar barriers. They encounter a number of problems when wanting to take courses such as foreign languages, math and sciences, and vocational education because local schools often can not afford to provide many advanced and specialized courses (Maher, 1982). Fortunately, advances in audio and video technology have made it possible to deliver formal education via interactive television. Interactive television (ITV) is a system that allows for live, two-way audio and video communication. In ITV environments, the learner and the instructor are physically separated, but they are brought together through the use of technology (Hughes, 1988). Furthermore, ITV can link multiple classes at various sites, and all students can see and hear the teacher and other learners (McClelland, 1987).

There has been a limited number of research studies conducted on ITV because it is a new form of distance education and has not been in existence for long. ITV in the USA is often used for teaching at a distance. This is called distance education. Keegan (1986) cited six characteristics of distance education environments:

- The separation of teacher and learner which distinguishes it from face-to-face lecturing.
- The influence of an educational organization which distinguishes it from private study.
- The use of technical media to unite teacher and learner and carry the educational content.
- The provision of two-way communication.
- The separation of the learner and the learning group.
- The participation in an industrialized form of education (p. 42).

Hughes (1988) stated that "because the technology of interactive television is still at an early developmental stage, programming using this technology remains scattered and often idiosyncratic in design, implementation, and evaluation. Thus, no sampling of data for programming in the field can be truly 'representative' " (p. 2).
According to McClelland (1987) "ITV technology links subcultures of learners together into the larger culture of an expanded classroom where interaction may or may not develop in ways that encourage participation from all persons and sub-groups" (p. 6). These subcultures are equipped with video cameras and monitors that are set up so teachers can switch cameras to send views of themselves, students, or visuals, to students at remote sites. The intent is for the technology to be so simple that a technician is not needed.

Currently, two-way instructional television has been used either to facilitate the offering of courses, or to provide opportunities for specialization and additions to the existing curriculum. The integration of two-way instructional television into the core curriculum as a part of the basic instructional delivery system has not yet been widely attempted (Hughes, 1988).

Hughes stated that the use of ITV primarily occurs with four types of courses:

1. Low-enrollment courses (e.g. advanced mathematics, science and business courses.)

2. Low-enrollment course sequences (e.g. particularly foreign language tracks: Latin, German, and French).

3. Limited staff courses (e.g. essentially in specialization areas where qualified staff and/or instructional resources are only available to a single school district).

4. Special interest courses (e.g. pilot's training, theater criticism, computer graphic design).

The department of vocational and technical education at the University of Minnesota conducted four case studies in which they investigated how teachers and learners interact in classes that are held in an ITV context (McClelland, 1987). They also tested to discover what ways, if any, did ITV constrain or facilitate teaching and learning. The four case studies examined interactions in two high school classes: a vocational education class and a foreign language class; and two adult education classes: a professional education class and a food preservation class. The studies employed a naturalistic research design, and data were collected in the form of videotapes of class sessions and interviews with students and teachers.

One significant conclusion derived from the study was that ITV technology did not appear to be a significant intrusion on the flow of lessons. The data indicated that approximately four percent of the comments in secondary classes related to adjusting or using the technology. When the lesson was stopped to correct equipment problems, usually it was because the teacher had not checked the equipment before class. Students in secondary classes quite often assumed the responsibility for making technical adjustments to ITV equipment.

The researcher observed that teachers in the secondary classes exhibited a good deal of skill in coordinating the technology and the classroom activities. For example, the foreign language teacher would switch to the overhead camera in order to present new words for translation and to emphasize correct spelling. In contrast to the secondary teachers who had used ITV systems for five months prior to the experiment, teachers of the adult education classes were using the system for the first time during the experiment. These instructors had received limited instruction on the use of the hardware prior to actually using it in class; therefore, many of the camera views and learning activities lacked coordination. This evidence suggested that teachers need instruction and practice using the ITV system before effective use of it will occur.

A second significant finding of the case studies was something called the "invisible class". An invisible class, or the concept of invisibility, existed when a remote class did not participate heavily, and in essence was not seen or heard from much by others. In the secondary classes, one remote site had considerably fewer students than the others. According to the researcher, this class was in a sense "invisible". That is, the teacher called on members of this class significantly fewer times than the other classes and the students in this class interacted much less than students from the other classes. The researcher stated that this may have been because of the small number of students in the class. Currently, there is no research that supports the notion that the "invisible" class phenomena lessens opportunities for learning. However, ITV teachers should be alert to this possibility until more research is conducted. According to McClelland (1987), teachers can help minimize invisibility by facilitating participation by all and "humanizing" the ITV classroom environment. For example, in the secondary classes, teachers focused on individuals and developed rapport by calling on students in remote sites.
There have been several studies on distance education conducted at Iowa State University. Many of these studies examined the attitudes of those using distance education systems. For example, Johnson (1988) conducted a study to describe the attitudes of high school students toward interactive televised instruction relayed using communications satellites. Data were collected by circulating questionnaires to approximately 400 high school students. Results indicated that students generally had positive attitudes toward ITV, although they tended to prefer traditional instructional methods. The data also indicated that the attitude of high school students toward ITV was more positive when there were other students in their local classrooms.

In a second study, Chinn (1990) examined the attitudes of interactive television teachers toward their ability and training to teach on interactive television. More specifically, the purpose of Chinn's study was to "determine teachers' attitudes toward interactive televised instruction, the type of training received and personal perceptions of self-efficacy with regard to being interactive TV teachers" (p. 23). Chinn surveyed approximately 200 K-12 interactive television teachers from throughout the United States and found that attitudes toward teaching on television were slightly negative although the respondents tended to have positive attitudes toward the training they had received. Chinn stated that this was probably because some training needs had been met, but others had not.

Chinn suggested other research issues in distance education. Some of these include the investigation of the role of teacher educators who prepare ITV teachers, and the criteria employed by them when they develop training for interactive television teachers. Chinn stated that "the issue of how decisions are made by trainers with regard to what constitutes a training program for television teachers should be addressed" (p. 101).

The attitudes of school administrators and teacher leaders toward satellite delivery of courses for high school credit was described in a study by Neuberger (1989). Neuberger found that the two groups generally had positive attitudes toward interactive satellite instruction, although school administrators tended to be more positive than teacher leaders about the use of satellite technology. It was also found that school administrators seemed to favor less regimented control on the use of the technology in schools than did teachers.

Albright (1988), conducted a study to determine the procedures for developing and delivering college level courses via satellite. The study indicated that at the university level, classes offered by satellite may be an effective method of providing college credit. However, well planned instruction and organized student support services were needed for less motivated individuals. According to Albright, "a course must be based on clearly established learner needs, and course objectives must reflect a careful assessment of those needs" (p. 209). Albright stated that less motivated students may not be as tolerant of uninspired instruction and underutilized video as highly motivated students.

**Recommendations For Use**

Although two-way interactive television is technically "the next best thing to being there" it is still a technology delivery system that is intrinsically remote. Because of this, teachers and administrators must put forth a great deal of effort in order to add a human touch to the delivery system. The following is a list of guidelines for personalizing ITV classrooms (Hughes, 1988).

- The ITV teacher should emphasize and encourage active student participation.
- The ITV teacher should meet face-to-face (if at all possible) with the remote site group prior to the first scheduled class.
- ITV teachers should learn students' names immediately. (This may be facilitated by taking photographs of each class during the meeting prior to the first scheduled class.)
- ITV teachers should schedule informal and formal face-to-face meetings with the class during the school year.
- When teaching on ITV systems, teach to the camera. This gives the student the impression of eye contact which is critical to personalization.
- Do not ignore the "home" site students. Home site students are those students in the room where the ITV class is originating.
• Use the attributes of the audio and video technology to enhance presentations. For example, use the zooming capabilities of the video camera to capture and display details.

• If possible, teachers should travel to, and teach from, each remote site.

• Devise formative evaluation techniques in order to assess the success of the class as it is being taught.

• Be cognizant of school rivalries. Avoid pitting one school against another. Try to have heterogeneous groups at all sites.

Hughes (1988) and others have stated that staff development is the key to the effective use of an ITV system. Teachers who will use the system must feel comfortable with and confident of their ability; therefore, appropriate training that provides both information and experience must be provided. The following is a list of training recommendations.

ITV training sessions should:

• Provide hands-on guided practice on the use of ITV technology.

• Have experienced ITV teachers present to answer questions, provide solutions to potential obstacles, and assist teachers with problems they may encounter.

• Incorporate the effective elements of instruction as major parts of the training session.

• Provide teachers with an overview of the technology and how it works.

• Include periodic follow-up inservices and on-site coaching.

• Include teachers who volunteer for ITV training.

As research directions on ITV are being formed, Hughes (1988) recommended that further research in two-way interactive instructional television should ask the following kinds of questions:

• What kinds of courses should make the most productive use of interactive television?

• What kinds of learning styles can be successfully integrated with interactive television technology?

• What age levels can be most appropriately taught using ITV?

• Can conventional video, audio-visual, and computer technology be integrated into a multifaceted instructional system? If so, to what extent can this be done?

SUMMARY AND CONCLUSION

One- and two-way instructional television have been used as effective delivery systems that facilitate student learning. The research on one-way instructional television has produced the following characteristics of effective ITV programs:

• Key concepts are repeated in a variety of ways.

• The material is entertaining as well as informative.

• Trained communicators are used to present information.

• The programs encourage and provide opportunities for students to participate in learning activities.

• The length of programs should be matched to the attention span of the intended audience.
Two-way instructional television is an emerging instructional delivery system that has the capability of overcoming physical barriers. Two-way ITV allows for live audio and video communication between teachers and students who are not at the same location. Although a limited number of studies have been reported in the area of two-way ITV, existing research has suggested that the following techniques can personalize the two-way instructional classroom. ITV teachers should:

- Emphasize and encourage active student participation.
- Meet face-to-face (if at all possible) with students at the remote sites of the ITV class prior to the first scheduled class.
- Schedule informal and formal face-to-face meetings with the class during the school year.
- Teach to the camera. This gives the student the impression of eye contact which is critical to personalization.
- Travel to, and teach from, each remote site if possible.
- Devise formative evaluation techniques in order to assess the success of the class as it is being taught.

Researchers in the area of two-way ITV have also made recommendations on how to prepare teachers to use two-way ITV systems. The following is a listing of those recommendations. ITV training sessions must:

- Provide teachers with an overview of the technology and how it works.
- Provide hands-on guided practice on the use of ITV technology.
- Incorporate the effective elements of instruction as major parts of the training session.
- Have periodic follow-up inservices and on-site coaching to ensure long term training benefits.
- Be used with teachers who volunteer for ITV training.

Research on Computer Based Learning (CBL)

"What we need to do, then, is to educate as though this technological revolution is what it really is--the third learning revolution--the most important change in learning since the 16th Century"
Mary Alice White (1987, p. 63)

INTRODUCTION

"In the 1980s, no single medium of instruction or object of instructional attention produced as much excitement in the conduct of elementary and secondary education as did the computer" (Becker, 1990). Over the last decade, the number of microcomputers in schools has increased nearly 50-fold from about 50,000 to roughly 2,400,000. As a result, much of the current research interest in technology in education is currently concentrated in the computer area.

This research, which is focused on the use of the computer in education, will be reviewed in this section. The section begins with a clarification of current terminology in the field, then moves to a discussion of various systems for conceptualizing and categorizing computer uses in education. Problems with current research in the area are then discussed. The review of the research begins with a description of two large scale review studies, then presents results of studies in particular areas. Two major descriptive studies are also included, as are suggestions for future directions in CBL research.
TERMINOLOGY

With the rapid increase in the importance of educational computing has come some controversy over terminology to describe the field. The terms CAI (computer assisted instruction), CBI (computer based instruction), CBL (computer based learning), CBE (computer based education) and CAL (computer assisted learning) are all used to describe computer applications in education. Although the term CAI sometimes refers broadly to all educational software, it usually connotates a programmed learning approach in which specific educational objectives are achieved through step-by-step instruction. The term instruction in CAI is usually interpreted as the computer delivering information to the student. Thus, for many, the term CAI now refers to drill and practice and tutorial software that implies a behaviorist approach to using computers in classrooms.

CBL is currently gaining popularity as a term that describes all student learning that is related to the computer. This term is considered more general, by some, because the word learning more naturally encompasses situations where the computer is used as an educational tool, but is not delivering information or instructing the student. In this paper, CBL will be used as the most general term describing computer applications in schools.

PROBLEMS WITH THE RESEARCH

Much of the early research on computer uses in schools replicated the errors of earlier media comparison studies (Clark, 1985). Studies tended to focus on "the computer" as the independent variable and thus assumed that the computer itself was somehow affecting the learning process. In addition, the dependant variables for many of these studies were inadequate. Like the media comparison studies, early work tended to use traditional achievement measures as outcome measures. In light of some of the newer uses of computers in classrooms, however, it seems apparent that these traditional achievement measures are no longer completely adequate dependant variables. Typical dependant variables include final test scores and scores on standardized achievement tests. As computer work in classrooms begins to emphasize the development of problem solving and metacognitive skill in students, it seems clear that measures of these skills must be developed and used as dependant variables for studies. The lack of such instruments is presenting a serious problem to researchers in the field, and many studies are flawed by inappropriate dependant variable measures. There are, however, several researchers working in this area and more appropriate outcome measures are emerging. (Haechan & Baker, 1989; Rebok, 1989; Shoenfeld, 1985).

In addition to problems with independent and dependant variables, much of the research work in the area of CBL, like research work with other media, has been criticized because of design problems. In many studies there are no controls for either the curriculum content or the teaching methods. Different teachers are often used for the computer and non-computer groups and no control is made for the teacher's effect. Clark points out that the effect size of .5 cited in the Kulik meta-analysis of CBI at the college level was reduced to .13 when the same teacher developed all competing presentations (Clark, 1985). In addition, evidence suggests that the novelty effect explains many of the results favoring computers in the study (Clark & Salomon, 1986; Clark, 1990). Thus, the design problems found in media studies are also prevalent in the computer area.

CATEGORIES FOR CBL

In order to focus the independent variable in CBL research, it is important to categorize the particular use of the computer being studied. Several authors have suggested categories of computer use that help achieve this; four such systems will be reviewed here. Two of these systems classify by type of software, one by the state of the learner in the learning process and one is a more general system outlining anticipated computer uses in the future. Each should provide researchers with assistance in sorting out the particular aspect of computer use they are studying. This should help achieve a more explicit definition of the independent variable in CBL research.

The traditional method for classifying educational uses of computers involves categorizing computer applications by type of software. Although there is some variation in the specific definitions of these categories, the categories typically include: drill and practice, tutorial, simulation, problem solving, tool and computer managed instruction (Simonson & Thompson, 1990).

One of the first uses of the computer in education was for drill and practice in arithmetic and reading. As early as 1963, Patrick Suppes and Richard Atkinson of Stanford University were producing computer programs that elicited
a student response, provided immediate feedback, and then proceeded to another problem of appropriate difficulty. Much of the early research in computer education focused on examining the effectiveness of this approach and examining alternative methods of providing feedback to students.

Computer tutorials, as the name implies, are programs that are designed to act as tutors or teachers for students. In a tutorial, concepts are presented and students are given an opportunity to interact with the concepts. Much of the early research in this area examined the question, "Who is the more effective and efficient teacher, the computer or the human?"

A simulation is a representation or model of an event, an object, or some phenomenon. A simulation is generally an incomplete model that contains the essential elements of an event. Although educational simulations existed long before computers, the computer has made the use of the educational simulation practical in the classroom. Early research on the effectiveness of simulations has provided inconclusive results; some have suggested that this is due to the use of achievement tests as outcome measures for these experiences. Since simulations are designed to give students an opportunity to learn and use problem solving skills, tests should measure these skills and not just evaluate content knowledge.

Problem solving software, like simulation software, is designed to use computer capabilities to enhance the teaching and learning of higher order problem solving strategies. Most problem solving software is similar to simulation software because students are placed in situations where they can manipulate variables and then receive feedback on the results of these manipulations. Simulations, however, are attempts to model real-life situations and objects, whereas problem solving software lessons are a more general category of software that includes less specific educational environments. Research in this area has also been somewhat problematic because of the lack of effective measures of problem solving and higher order thinking skills.

Tool software is the category of educational computing software currently receiving the most attention from educators. Tool software is used to enhance the teaching and learning process in all subject areas (Sheingold, Hawkins, & Kurland, 1984). Tools include: word processors, data base managers, spreadsheets, telecommunication software, and graphics packages. These packages are referred to as tools because, like pencils, rulers, calculators and chalk, they help students and teachers accomplish cognitive tasks, but do not specify the content of these tasks. Thus, a word processor can be used for creative writing or for completing laboratory reports. It has been asserted that the use of tool software will enable teachers and students to concentrate on the development of more sophisticated cognitive skills because the computer can perform many tedious tasks. It has also been stated that computer tools can act as "cognition enhancers" to expand the capabilities of the student (Dede, 1987). Little empirical evidence exists, however, for this claim. Research on one tool, the word processor, will be reviewed later in this paper.

Computer managed instruction (CMI) refers to using the computer as a tool to help the teacher perform administrative tasks in the classroom. The computer is used to keep grades, arrange reading groups, write letters to parents and generally help the teacher with management. Since this review is focused on use of technology in the learning process, this application will not be reviewed. Many educators are suggesting, however, that CMI is an important first step in the teacher education process.

A second categorization system was proposed by Robert Taylor in his book, The Computer in the School: Tutor, Tool and Tutee (1980). As is suggested in the title of his book, Taylor pointed out that the computer can be used as a tutor, as a tool, and also as a tutee. Although the concepts of computer as tutor and tool have already been presented in this paper, the concept of computer as tutee requires more explanation and provides an interesting perspective on computer use in schools.

Here, the "traditional" role of the computer in education is reversed. Instead of the computer presenting information to the student, the student is teaching the computer. In order to teach the computer, the student must learn a language the computer understands and thus must work with programming. Taylor argues that "the computer makes a good tutee because of its dumbness, its patience, its rigidity and its capacity for being initialized and started over from scratch" ( p. 4). He goes on to suggest that students can teach the computer to be a tutor or a tool and, "Learners gain new insights into their own thinking through learning to program, and teachers have their understanding of education enriched and broadened as they see how their students can benefit from treating the
computer as Tutee. As a result, extended use of the computer as Tutee can shift focus of education in the classroom from end-product to process, from acquiring facts to manipulating and understanding them” (p. 4).

Another useful classification system for educational uses of the computer has been created by Rex Thomas and Peter Boysen. Thomas and Boysen contend that the traditional method of classifying by type of software is of no use to the teacher attempting to integrate the computer into the classroom. (Thomas & Boysen, 1984). Knowing that a program is a simulation or a tutorial does not help the teacher who wants to know where and how to use the program in instruction. In order to address this problem, Thomas and Boysen suggest a taxonomy of computer use where the classifying variable is the state of the learner with respect to the material. The major value of the Thomas/Boysen taxonomy is that it gives the teacher direction about where and how to use the computer in instruction. One interesting sidelight of this system is that the same program might be classified in different areas depending on how the teacher uses the program in instruction.

At the lowest level of the taxonomy, the learner has not yet received formal instruction about a topic and computer programs are used to set the stage for later learning. The first level is termed experiencing. Used prior to instruction, computer lessons may provide experiences and/or models for later instruction. For example, an economics simulation program might be used as an experiencing lesson prior to a formal unit on simple economics. Some of the basic concepts presented intuitively in the simulation would be common experiences for all students and used as points of reference in formal instruction.

At the next level, the student is ready for formal instruction and the computer is used to deliver information. This level is termed informing. Programs used at this level are most frequently tutorial software.

Reinforcing programs are used after formal instruction and are assigned to strengthen specific learning outcomes. Drill and practice programs will frequently be used at this point in instruction, but sometimes a tutorial will present information in an interesting alternative fashion, and thus, might provide a useful mode for reinforcing.

Integrating programs provide an opportunity for the student to apply previous learning to new situations as well as to associate previously unconnected ideas. Students are frequently asked to manipulate and apply information beyond the classroom presentation. Simulations are especially appropriate for learners at this level.

At the utilizing level, the computer is used as a tool in the manipulation of the subject matter. At this stage, the student might use a database to examine questions about whales, use a statistical program to analyze research data or use a spelling checker to check the spelling in a document.

The Thomas/Boysen taxonomy offers a rich system for helping researchers define computer use. In several studies, researchers used the system to compare computer lessons used in different places in the instructional process. Thus, questions like, "Is a simulation more effective used at the experiencing level or at the integrating level?" can be effectively studied.

In an article forecasting educational computing categories of tomorrow, futurist Christopher Dede suggested that the next generation of educational software will feature cognition enhancers that enable human beings to extend their cognitive powers through computer applications (Dede, 1987). Dede suggested that three types of cognition enhancers are emerging: empowering environments, hypermedia and microworlds. Empowering environments are computer tools designed to efficiently handle the routine aspects of a task so that the human user can focus on higher level activities. Dede suggests the possibility of such cognition enhancers in writing, art and even anthropology.

Dede defined hypermedia as a framework for non-linear representation of symbols (graphics, text, images, code), in the computer. In a hypermedia system, data are accessible through associations. Such systems can be viewed as realistic extensions of human memory. Apple's Hypercard system and IBM's Linkway are two examples of software taking this approach. Hypermedia educational applications are reviewed in a later section of this paper.

Finally, Dede suggested that computer microworlds offer possibilities for expanding cognition. A microworld allows the user to explore and manipulate artificial realities. In such an environment, students might explore the principles of gravity by manipulating and exploring a microworld where baseball is played in earth's gravity and then in the gravity of various planets.
Dede suggested that cognition enhancers can be considered intelligence amplifiers (IA) and that IA may be a more practical direction area of investigation than Artificial Intelligence. His concept is that in IA environments the human performs the task he/she does best, the computer performs the tasks it does best, and the intelligence of each is amplified by the partnership.

All three of Dede's cognition enhancers are clearly examples of computer environments that emphasize student involvement and control and "learning while doing". It appears that these themes will be strong ones in computer applications of the future. Simulations, problem solving environments, tool and tutee uses, and experiencing and integrating uses all seem to be areas of potential growth and emphasis in future research on CBL.

All the categorization systems summarized here help provide direction for more specifically defining independent variables in computer based learning research. It is interesting to note that many of the early studies reviewed in meta-analytic and traditional reviews of computer based learning were combined regardless of the independent variables. Thus, reviewers were searching for "computer effects" rather than isolating particular effects of particular uses of the computer. Studies of simulations used prior to formal instruction were combined with studies of drill and practice software used after formal instruction. Any consideration of the findings from these studies must take this combining of independent variables into account.

MAJOR REVIEWS

The meta-analytic studies performed by Kulik and his colleagues are still probably the most widely cited review studies on computer based learning. Like a traditional review, a meta-analysis is designed to summarize and synthesize research findings in a particular research area. A meta-analysis differs from a traditional review in that a summary statistic, called the effect size, is computed for each study and these effect sizes for each study are combined and one statistic for the combined effect size is reported. Thus, in one sense, a meta-analysis is a quantitative review of the literature in a particular area.

Kulik completed three large meta-analytic studies; one study examined effects of computer based learning on elementary students, one examined effects on secondary students, and one examined effects on college students. Kulik's meta-analysis at the elementary level revealed an improvement in student achievement with an effect size of .47 standard deviations. Kulik, Bangert and Williams (1983) analyzed 51 studies of CBE conducted in grades 6-12. Overall, they found that the CBE raised student examination scores by .32 standard deviations and also had positive effects on student attitudes and on the amount of time needed for instruction. Findings in a college level study (1980) were similar, with the improvement in student achievement at .25. Kulik concluded that computer approaches were most effective for elementary students and least effective for college students.

Kulik's most salient conclusions were that computer based learning approaches improved student achievement, saved student and teacher time, and improved student attitude toward school and particular subjects. His work has been frequently cited as proof that CBL approaches are effective.

Although Kulik's conclusions have been widely cited, his methodology has received severe criticism from many. Of great concern is the fact that a high percentage of the studies included in his review were studies performed prior to the widespread use of microcomputers in schools. Many suggest that the studies performed using mainframe computers are of questionable applicability for today's situation.

In a more recent review of research about computer based learning, M.D. Robyler attempted to update the work of Kulik and others (Robyler, 1988). Robyler reviewed studies performed in the 1980s and provided useful information about both research procedures and outcomes. Robyler described outcomes in the areas of attitudes, content, application type, grade level and types of students. In all areas, she compared her results to those of previous reviewers.

Attitudes toward school and content areas were the most frequently measured attitude variables in the studies in Robyler's review, and, like past reviewers, she found the effect was significant and positive. She suggested that improving students' self-image and self-confidence through computer use was a variable that needed further study. Although there has been considerable recent discussion on this topic, she was able to locate only three studies with data on this issue.
The Robyler review confirmed earlier reports that computer applications were more effective for teaching mathematics than reading and language skills. She noted, however, that the variability in the reading studies was high and that this might have accounted for some of the differences observed. She found the greatest effects in the science studies, but noted that the small number of studies reviewed in this area made these results only preliminary. Robyler also noted that using computer applications for teaching cognitive skills (problem-solving, critical thinking) yielded about the same effects as for reading and mathematics.

Robyler found that data on specific computer application types (for example: drill and practice, tutorial, simulation) were difficult to analyze because of their relation to specific subject matter. She suggested that at the time of her review, the only areas with enough studies to analyze in this way were in reading and mathematics. She also noted that the high positive effects in science were found in studies that used simulations for unstructured work. Effects produced as a result of drill and practice work in science were much lower. Robyler indicated that more study in this area is appropriate and that "Clearly, the effectiveness of various types of CAI applications varies according to content area and skill being taught" (p. 122).

Contrary to the results of earlier work, Robyler found that effects from computer use were highest at the college level and lowest at the secondary level. She suggested that computer applications can be effective at higher levels (college), and that perhaps CBL might be most effective at this level.

Robyler found a trend, previously reported, for computer use to be more effective when used with low achieving students. She stated that, "It should be noted in this summary as it was in the summary of past reviews that software especially designed for slow learners may be more effective with them than software designed for the general population" (Robyler, p. 123). She found differences in effects for males and females to be inconclusive, but strongly suggested that this was an area in need of further study.

Robyler suggested that future research in computer based learning should concentrate on:

- Applications in various skill and content areas.
- Computer applications in English as a Second Language (ESL).
- Word processing use.
- Creativity and problem solving with Logo and CAI.
- Effects of computer use on attitudes and drop-out rate.
- Differential effects of computer use on males and females.

Although information from reviews of research in computer based learning provided valuable insights, the tendency for the reviews to include media comparison studies must be questioned. Clearly, the studies that focus on effects of specific attributes and uses of the computer on specific learner outcomes are difficult to combine and analyze. It should be noted that the majority of the cognitive dependant variables in the studies included in the Kulik and Robyler reviews used standardized achievement measures. A brief description of some exemplary studies in the area of computer based learning follows; these studies are intended as models for future work in the area.

STUDIES IN SPECIFIC AREAS

In her recommendations for research in computer based learning, Robyler emphasized the need for more work on the cognitive effects of working with Logo and other programming languages. A study of the cognitive consequences of inquiry-based Logo instruction provides one useful model for this type of computer based learning research. In this intra-medium study, forty five third grade children were assigned randomly to one of two Logo-based instructional conditions or to a third, problem-solving software, control condition (Lehrer & Randle, 1987). One Logo group was taught how to apply general programming strategies, such as problem decomposition, to solve Logo graphic problems. The second Logo group used Logo to solve geometry problems; here Logo was used as a subject matter tool. The third group used problem solving software. All three instructional conditions emphasized
inquiry based methods. Thus, the independent variable in the study was not "the computer," but instead was a particular approach to using the computer.

Outcomes were measured in three areas: knowledge of geometry, metacognition and epistemic cognition. Children in the two Logo groups scored significantly better on one planning task than children in the third group. Children in the Logo groups also developed more dynamic representations that allowed them to proceed further analytically than their more visually oriented counterparts in the control group. No significant differences were observed in other areas, however.

The results of Lehrer's study suggested the need for more research examining possible problem solving and metacognitive outcomes from computer work with programming languages or other problem solving environments. His findings in the area of planning and learning geometry suggested fruitful avenues for further work.

Lehrer's study exemplifies appropriate choices of both independent and dependant variables. The independent variable in the study was computer based problem solving strategies and the dependant variable measures were all carefully constructed or selected to measure the appropriate cognitive outcomes.

The issue of the effects of programming experiences on student problem solving capabilities has been and continues to be a popular research topic in computer based learning. Although Lehrer's results are positive, studies in the area have not been conclusive (Kurland, Pea, Clement, & Mawby, 1986). In a review of the relevant issues in programming/problem solving research, Palumbo (1990) suggested that many studies in this area have not been sufficiently grounded in problem solving theory.

Palumbo (1990) also contended that programming/problem solving researchers should concentrate on designing the treatments to mindfully teach problem skills and should allow sufficient time for students to adequately master the programming language. He also suggested that future research should focus on high school age children, since the readiness of young children to learn programming languages is questionable, and studies of college age students have already yielded some positive results.

Another specific topic of increasing interest to CBL researchers is in the area of using the word processor in the teaching of writing. The largest increase in school use of computers from 1985-1989 was in the use of word processing (Becker, 1990). Becker stated, "English teachers stand out as the group that has begun to have students use the computer primarily as a productivity enhancement tool" (p. 5).

Research has revealed some positive results, but clearly indicates that use of the word processor alone will not improve student writing (Daiute, 1985). Early research has suggested, however, that with proper teacher interventions, word processing can improve student attitudes toward writing, increase the amount of time students spend writing, and also increase students' willingness to revise their writing (Wresch, 1987).

The effect of the word processor on student revision strategies has been an area of significant research interest. Clearly, the computer makes revising more convenient. Students tend to have a naive view of revisions. They focus on the word and sentence level rather than on looking at the logic and structure of their argument (Sommers, 1981). Research studies are beginning to examine the effects of teaching revision strategies in conjunction with using word processors since "making revisions easier is appropriate, but unless it is combined with knowledge of what revisions to make, revision alone may not lead to improvement in composition" (p. 277).

Reynolds and Hart compared two approaches to teaching revision techniques with a word processor and found that students who used cognitive mapping strategies made revisions that significantly improved their compositions as compared with students using the more traditional brainstorming and outlining methods (Reynolds & Hart, 1990). Here again, the focus of the study was not on the impact of the computer; both groups used the computer. The focus of the study was on determining the most effective strategies for use with the medium. Work in the area of collaborative writing provides another example of this intra-medium approach.

The use of the computer as a tool for collaborative writing experiences is an area of increasing interest currently yielding some positive findings (Daiute, 1985; Dickinson, 1986). One study compared the effects of cooperative, competitive and individualistic goal structures on student's writing products (Johnson, Johnson & Stanne, 1985). In this intra-medium study, all three groups used the computer as their writing tool. The results suggested that
computer-assisted cooperative instruction promoted greater quantity and quality of daily achievement and more successful problem solving than did the computer assisted competitive or individual learning. One very dramatic result was that girls' attitude toward learning were more adversely affected within the competitive condition. The study is a useful example of one that concentrates the independent variable on the approach rather than on the medium.

It seems clear that the area of computer assisted writing is a rich one worthy of more attention from researchers. The use of the computer in various stages of the writing process, in collaborative writing, and to enhance the writer's sense of audience are all areas in need of further work.

Gender differences in computer use, attitudes, and aptitudes have also been significant areas of study for researchers in computer based learning. Much of this work has been based on earlier research on gender differences in mathematics aptitude and achievement. Some researchers have suggested that the long-documented gap between male and female participation in elementary mathematics and physical science courses is now occurring in computer labs (Collis, 1985). Although results in this area are somewhat contradictory (Harvey & Wilson, 1985), several specific trends have emerged.

Several studies have suggested that males have more confidence in their abilities with respect to the computer and spend more time working with computers (Chen, 1986; Collis, 1985; Miura & Hess, 1983). One interesting trend in this area has been termed the "We can, but I can't" syndrome. Females tend to agree in the abstract about female abilities with the computer, but when asked about their own abilities, they judge themselves less than adequate (Collis, 1985; Chen; 1986).

General attitudes toward computers and computer use have also been studied. Betty Collis (1985) conducted a large-scale survey study in two British Columbia school districts and reported that significant gender differences in attitudes toward the computer existed and that these differences were clearly established by grade eight.

Several studies have examined differential use of computers by male and female students. Chen (1986) reported that more boys than girls enrolled in high school level programming classes and that this difference accelerates as the difficulty of the courses increased. He also reported that more boys than girls had home computers. When he examined data on the use of home computers, he found that boys who had home computers used them an average of more than 6 hours per week, while girls who had computers used them an average of 3.6 hours per week. In a survey of computer summer camp programs, Hess and Miura (1985) found that in the 23 summer programs they studied, boys outnumbered girls by a ratio of 3 to 1 at the elementary level and about 4 to 1 at the secondary level.

Additional studies demonstrated that parental and societal influences have discouraged female computer use. Chen (1986) found that more parents purchase a computer with a son in mind than a daughter. After surveying four popular computer magazines Sanders (1985) suggested that teachers and parents can hardly be blamed for expecting the computer users to be male. Ninety percent of the photographs, articles and advertisements were geared toward males.

Chen (1986) suggested that once females become involved with computers, many of the differences in attitude and aptitude disappear. He proposed several suggestions for increasing female computer participation, and has encouraged researchers to pursue these possibilities. Chen advocated:

• Paying closer attention to the processes of societal influence that affect female use.

• Using subject-matter courses in English, math, science, history, and other subjects to introduce computers. Avoid programming as the initial exposure.

• Emphasizing computer applications (graphics, databases, telecommunications) to encourage more female participation.

• Expanding the use of computers in schools into more "real world applications".
In addition, Sanders (1985) suggested that parent education is a necessary strategy to encourage female computer use. Sanders indicated that parents need to be made aware of the significance of technology education and the importance of encouraging their daughters in this area.

It seems evident that future research in this area should focus on interventions like those suggested by Chen that might improve female participation in computer activities. Simply re-documenting existing gender differences in ability, attitude and use is a much less useful avenue.

DESCRIPTIVE STUDIES

In addition to experimental and quasi-experimental studies about computer use in education, descriptive studies reporting "what is" in computer use in the schools have provided useful insights. Henry Becker and the Center for Social Organization at Johns Hopkins have conducted three large, national surveys of computer use in schools during the 1980s and his work is usually cited as the national "thermometer" on what is actually happening in schools. In Becker's 1983 study, he reported that students were using computers for drill and practice, programming in BASIC, and playing games, and that they spent very little time on the limited equipment that was available. He stated that students were probably learning more about computer hardware and software than about any content related material.

In his 1985 report, "Second National Survey of Instructional Uses of School Computers", Becker reported that teachers rarely used computers as a regular means of providing students with instruction or practice in traditional school subjects. Instead, computers were used primarily for enrichment or for teaching students about computers and computing.

In a similar study completed in 1990, Becker concluded, "In the past five years, changes in how schools use computers have been modest, but the direction that these changes are taking is fairly clear...the major development in computer activity at all levels but primarily in middle and high schools, has been a concentrated effort to use computers as productivity tools for expressing ideas and recording and analyzing information. Still the progress has been slower than the adherents of either one would like to believe." (p. 1).

In his 1990 study, Becker sampled 1,416 schools in the United States; his sample included one-third elementary, one-third middle and one-third high schools. He collected data on hardware, software, computer use and teacher attitudes.

Becker stated three major conclusions in his 1990 study. First, he suggested that despite the tremendous increases in hardware and software available in schools, "only a small minority of teachers and students can be said to yet be major computer users--that is; where a large portion of instruction, learning, or productive work in their classes is being accomplished through the use of computers" (p. 10). He cited teacher attitude and lack of teacher education on computer use as two major impediments blocking more effective and appropriate computer use.

Second, Becker suggested that the hardware available in most schools was inadequate to support the more complex computer learning environments available and advocated by futurists like Christopher Dede. He said that software publishers were severely limited by the constraints of older machines.

Becker's final conclusion was that word processing was the major computer learning activity in U.S. schools. He said, however, that word processing was not yet integrated into the teaching of writing and was taught for its own sake. However, he saw this as a natural progression in the use of this tool in writing instruction.

In addition to Becker's work, a second large-scale descriptive report of computer use in education was produced by the Office of Technology Assessment (OTA) in 1988. The report, titled Power On: New Tools for Teaching and Learning, described the current state of technology use in schools and provided recommendations for research and development efforts in this area (Porro, 1988). The report concluded: "OTA finds that, although new interactive technologies cannot alone solve the problems of American education, they have already contributed to important improvements in learning. These tools can play an even greater role in advancing the substance and process of education, both by helping children acquire basic skills and by endowing them with more sophisticated skills so they can acquire and apply knowledge over their lifetimes" (p. 4).
Authors of the OTA report reviewed research about computers in education and suggested that the body of research in the area created an incomplete and somewhat impressionistic picture. The report suggested, however, the following areas as the most promising current uses of computers in education:

- Drill and practice to master basic skills.
- Development of writing skills.
- Problem solving.
- Understanding abstract mathematics and science concepts.
- Simulation in science, math and social studies.
- Manipulation of data.
- Acquisition of computer skills for general purposes, and for business and vocational training.
- Access and communication for traditionally unserved populations of students.
- Access and communication for teachers and students in remote locations.
- Individualized learning.
- Cooperative learning.
- Management of classroom activities and record keeping.

The report emphasized the need to avoid concentrating on a single use of technology and stated, "OTA finds that the varied capabilities of the technologies are key to their power" (p. 11).

The need for further research and suggested directions for this research were also covered in the report. "Federal research should include studies on both the educational effectiveness and cost-effectiveness of currently available technologies addressing traditional goals, and studies of innovations that push the boundaries of learning and cognition." (p. 10). The study concluded that the following areas exemplified the most promising research directions:

- Intelligent tutoring systems that can make the services of an expert and responsible tutor regularly available to the learner.
- Applications that exploit the computer as a flexible multimedia controller, enhancing curriculum with the richness of video, graphic, and audio representations of information.
- Simulations, microworlds, and exploratory laboratory experiences in all disciplines that enable students to gain understanding through exploration, manipulation and guided discovery.
- Integrated tools and "intelligence extenders" that help students move beyond low-level tasks and concentrate instead on more cognitively demanding learning and problem solving.
- New assessment measures that track learning, diagnose students' conceptual understandings, and evaluate the attainment of non-trivial skills.
- Design tools, authoring systems, and knowledge kits that enable teachers to create and shape their own teaching materials, to modify curriculum, or develop individualized lessons for their students.
• New curriculum based on a changing vision of the skills students need in the information age, shifting much of the emphasis from what-to-learn to how-to-learn.

The report concluded that in order to pursue necessary research in the directions indicated, closer cooperation between various members of the research community and the classroom must be facilitated. The need for cooperation among the following fields was advocated: cognitive science, artificial intelligence, computer science, anthropology and sociology, psychology, instructional design, and education. The need for classroom based research was also emphasized.

DESIGN ISSUES

In addition to research on CBL effects on learning and descriptive work on the current state of CBL in schools, numerous researchers have focused on discovering the most effective means of designing CBL experiences for students. This has included: work in design of the student-computer interface, work on sequencing topics in CBL lessons, work on writing introductions, interactions, remedial branches, reviews and tests, work on tailoring CBL interactions for specific performance levels, and work on evaluating and revising CBL (Criswell, 1989).

The student-computer interface is one of the most unique features of CBL. Research in this area involves one of the most important design issues for creators and evaluators of CBL and has been chosen as the design issue for review in this paper. Research on student-frame interface and student-computer dialogue will be considered.

Researchers have determined several physical factors that help students clearly view the computer monitor (Diffrrient, Tiley & Harman, 1981). Screen lighting should be brighter than room lighting. The student should view the screen from a distance of about 16 inches and the distance from the chair up to the computer should be from 14 to 35 inches. Students should view the screen at a 90 degree angle and the screen should be located for minimal eye and head movement.

Galitz (1981) interviewed users to determine desirable screen characteristics and summarized responses:

• An orderly, clean, clutter-free appearance.

• An obvious indication of what is being shown and what should be done with it.

• Information located where expected.

• A clear indication of relationships between information on the screen.

• Simple English.

• A clear indication of options.

• A clear indication of exit procedures.

• A clear indication of when an action could make a permanent change in operation.

It has been suggested that one approach to avoiding clutter on the screen is to divide it into functional areas. One author indicated that a good test for screen design is to determine if all elements can be identified without reading the words on the screen (Galitz, 1981). Functional areas might include:

• Orientation information.

• Text.

• Graphics.

• Questions.
• Space for student responses.
• Space for feedback.
• Directions for advancing to the next frame.
• Menu of options.

In terms of text screens, simple principles of effective screen design can be summarized in four major points (Criswell, 1989):

• Keep screen format consistent.
• Use uncluttered frames.
• Highlight important items.
• Write readable screens.

Certainly the design of the screen is an important issue for both researchers and developers in the area of CBL. A second significant area of interest in the student/computer interface is the student-computer dialogue.

Students usually interact with computers by using menus of options, short answers to queries, and a student help-request feature. In addition, in a natural language system, the student and computer talk to each other in English sentences (Criswell, 1989).

Menu design involves five major factors: order of options, selection codes, menu layout, menu content and control sequencing. The order of options should be clear and options should be grouped in a meaningful way. Selection codes should allow a student to select an option by typing the first letter of the option rather than using arbitrary responses like a, b or c.

Principles for menu layout are similar to those outlined for screen design. Basically, the menus in a program should be simple and consistent. If the number of options in a menu exceeds 10 to 15, the designer should construct a menu hierarchy using two screens. Control sequencing refers to the ability of the menu to allow experienced students to skip over intermediate menus. A well-designed menu should allow quicker, easier access by the experienced student.

In contrast to the menu format, natural language dialogues allow the student to respond freely using his/her own words and to converse with the computer about the topic under study. Natural language CBL systems are generally very difficult and expensive to build, and thus research in the area is limited. Some suggest that the flexibility of natural language dialogues will benefit the learning process and eliminate the stilted nature of menu-driven programs. Others suggest that such dialogues require too much student typing (Criswell, 1989).

In addition to menus and natural language interfaces, future CBL materials will also enable intelligent interfaces with the student. These interfaces will adapt to the student and contain three critical features (Halpin & Moses, 1987). First, intelligent interfaces will elicit information on student goals and assess progress relative to these goals. Second, these interfaces will predict the behavior and preference of a particular student based on past behavior and preferences. Finally, the intelligent system will be able to access a variety of information to help the student succeed.

Student/computer interfaces are increasing in sophistication and effectiveness. Given current knowledge on screen design and student/computer dialogues which are based on communication theory research, computer lessons are increasingly improving their communication capabilities.

COST EFFECTIVENESS RESEARCH
On a practical level, researchers in the area of CBL must be concerned with the cost-effectiveness issue. The basic research question here is simple, "Are computers and related technology worth the expense?" One approach to this question has been to compare costs and effects of CBL approaches with other approaches.

Levin and Meister (1985) discussed the results of a recent study comparing the costs and effect of CBL with cross-age tutoring. Their conclusion was that CBL, while effective in teaching elementary reading and mathematics, was not as cost effective as peer tutoring. The study came under immediate criticism (Niemiec, Blackwell & Walberg, 1986), yet the issues raised by it certainly deserve further investigation.

Cost effectiveness research can easily revert to the naive approach of the media comparison study. Researchers must recognize that much of what computers will be used for in the future can not be accomplished in any other way. "Comparing programs using technology to traditional curricula rarely yield useful information since new programs have goals attuned to technological change, efficiencies attributable to technology, revised roles for students, and new responsibilities for teachers....Often material taught in technologically based programs simply can't be taught in another way, and therefore is cost effective by any criteria" (Linn, 1986).

A useful approach to cost effectiveness research is to compare cost effectiveness of alternative approaches to CBL. This type of research is significant because it shifts the emphasis from whether or not to use computers to the more relevant question of how computers can most effectively and efficiently be used in various instructional situations (Porro, 1988). This appears to be the most useful direction for cost effectiveness research.

SUMMARY AND CONCLUSIONS

It seems clear that research in CBL remains in its formative stages. Early work tended to concentrate on the effects of the computer on student learning, while more recent work is evaluating more specific independent variables.

Reviews of research in CBL have indicated that, in general, students can learn effectively from computers and that in some cases, computer work improves student achievement and attitude toward subject matter. Early studies suggested that CBL work was most effective at the elementary level and least effective at the college level. Later work, however, has reversed those findings. Although reviews of research on CBL are frequently cited as evidence for the use of CBL, the assumptions involved in combining studies using different types of CBL in different subject matters has been questioned.

The thrust of current research is no longer on comparing CBL with other media or with the teacher, but in determining what specific computer environments can best enhance student learning and in determining which instructional approaches used in conjunction with the computer are most effective. Many studies are designed as intra-medium studies; these studies compare different approaches using the computer in an attempt to discover the most effective instructional approaches. Current research tends to focus on computer environments that have the potential to improve student problem solving and information handling skills. Developing assessment tools to measure these outcomes is a challenge for researchers. Some of the most promising areas for future efforts include:

- Research on the effects of programming experiences in developing problem solving skills in students.
- The use of the computer in the teaching of writing.
- The use of simulations and microworlds to teach higher order problem solving skills.
- The use of tools to enhance learning tasks.
- The development of new curricula focusing on learning how to learn.

Recent research and development efforts in computer based learning points toward radically changing the roles of teachers and students in schools. Computer environments are beginning to enable more active and individualized learning on the part of students and to encourage teachers to serve as facilitators of this learning rather than as deliverers of knowledge. These potential changes in teaching and learning, based on cognitive theory, could cause
radical re-structuring of schools. In practice, however, most teachers and schools have not yet adopted and integrated these newer computer based learning approaches (Becker, 1990).

Research on Hypermedia

INTRODUCTION

The newest form of educational technology is a combination of technologies known as hypermedia. Because of the newness of hypermedia, research issues concerning its use in education are in formation. Not a great deal of research on hypermedia has been conducted and thus, definite directions for, and recommendations from hypermedia research are limited. This section will begin with a definition of hypermedia, review the research that has been reported on hypermedia, and discuss questions and issues recommended for future research.

DEFINITION

A single definition of hypermedia has yet to be agreed upon by those in the field. It appears that many educators are confusing hypermedia with multimedia and ignoring the differences between the two. Whereas multimedia refers to the use of a variety of media, hypermedia can be defined from the stem of the two words that make up the term. Hyper means nonlinear or random and media refers to information represented in many formats. Educational technology futurist Dede (1987) defined hypermedia as a framework for non-linear representation of symbols (p. 196). He considered hypermedia an external associational memory where the technology provides assistance in organizing and accessing information.

Hypermedia is viewed as an extension of hypertext, the electronic representation of text that takes advantage of the random access capabilities of computers; this random access capability permits the hypermedia user to overcome the strictly sequential medium of print on paper (Marchionini, 1988, p. 182). Hypermedia, according to Marchionini (1988), extends the means of information representation to include access to graphics, sound, animation, and other forms of information transfer (Marchionini, 1988, p. 182).

Hypermedia, then, combines methods of representation, like video, graphics, animation, and text, and connects the information represented in these formats in a multitude of paths in order to create an environment that affords immediate, yet random, access to large amounts of information. Such accessibility has been made possible by advances in information storage technology; in particular the computer has allowed the information storage and control necessary for hypermedia environments.

The nature of a hypermedia environment is interactive and exploratory. That is, such an environment requires the input or action of the user, and the user directs his/her own path through the environment. Computer technology affords the highest level of interaction between the user and the information stored in a hyperdocument. (A hyperdocument is the actual lesson or product of a hypermedia system. Hypermedia systems are hardware and software systems used to create and display hyperdocuments [Marchionini, 1988]). The computer is the most common component of hypermedia systems. The user interacts with the computer in order to access information. A typical hypermedia environment may include a videodisc and a computer interacting with the learner in order to allow access to graphics, video, sound, animation, and text.

IBM has produced a prototype hypermedia program that illustrates some of the power and flexibility of the approach. In this program, students are given the opportunity to explore numerous facets of Tennyson's poem "Ulysses". Students can select the voices of different actors who then read the poem or portions of the poem, students can view critics discussing various aspects of the poem, students can view some of Ulysses' adventures upon which the poem is based, students can view modern characters quoting from the poem in speeches, students can access more information about the poet, and students can ask for more information on specific words and references in the poem. Students are free to explore the information in the document with their own approach and locate the information about the poem that interests them. In total, the hypermedia document for the poem "Ulysses" makes the experience of the poem a meaningful reality for students.

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A second example of a hypermedia environment fitting the definition offered in this paper is an environment that allows students to explore information about bird anatomy. In this environment, students can select to explore the anatomy of a bird in depth, and can access line drawings, slides, video, text, and audio information about that part of the bird. Students can investigate a particular section of the bird, like the head, and then examine more deeply into a particular part of the head, like the eye. In one sense, the environment offers a multimedia encyclopedia of information on bird anatomy for the student. The student is given the opportunity to explore this environment in the way he/she chooses.

It is important to distinguish hypermedia from both multimedia and interactive multimedia. Multimedia is the combination of many forms of media or the combination and display of multiple visual or audio elements. Interactive multimedia allows the user to interact with the multimedia, however, this interaction does not alter the linear direction of the presentation.

RESEARCH ON HYPERMEDIA

Despite the limited number of studies conducted on hypermedia, research methods have followed the typical sequence of evaluation studies, media comparison studies, and aptitude treatment interaction studies. Abrams and Streit (1986) conducted an experiment to compare the effectiveness of interactive video to linear video for teaching a basic photography course to education majors. The results indicated that the interactive video group made significantly larger gains in achievement than the linear video group. The study also found that the use of interactive video had a greater impact on attitude than on achievement. Researchers speculated that one of the reasons users of interactive video presentations had higher achievement scores was because of the level of attentiveness required of the learner. With linear video the viewer can "tune out" the program, while with interactive video, learner involvement is required. That is, the viewer was quizzed as he/she proceeded through the information. If she/he missed the review questions, remedial instruction was provided by the lesson. Anandam and Kelly (1981) stated that interactive video "changes the student from passive observer to active participant." The linear video group cited the lack of opportunities for review and practice as a major shortcoming of the linear video.

In 1990, researchers at Vanderbilt University conducted three studies to test the benefits of interactive video-based instruction on student learning. All three studies focused on developing specific types of recognition and writing skills. In order to develop these skills, each of the three separate studies exposed students to detailed video examples of a particular writing style as opposed to solely literature-based examples. The objective of the interactive video-based instruction was to create environments that permitted sustained exploration by students and teachers and that helped students experience the value of exploring the same setting from multiple perspectives. This is known as anchored instruction and the single, yet comprehensive context of the video content is known as a macrocontext (Cognition and Technology Group at Vanderbilt, 1990; here after referred to as Vanderbilt).

The Vanderbilt team contended that their instructional approach allowed students to learn new information in the context of meaningful activities. They also contended that the meaningful, problem-oriented approaches to learning afforded by anchored instruction within a macrocontext were more likely, than fact oriented approaches, to produce knowledge that could be transferred to other situations (Vanderbilt, 1990).

The researchers chose visual as opposed to text formats because visual formats allowed students to develop pattern recognition skills. Second, video is dynamic, visual and spatial and students can more easily form rich mental models of problem situations. Third, interactive video technology has random access capabilities allowing teachers and students to instantly access information for discussion, and interactive video facilitates the exploration of the same context from multiple perspectives.

The results from all three studies indicated that recognition and writing skills improved significantly after the use of interactive video-based instruction. The results also indicated that the amount of improvement as a consequence of the use of interactive video was greater than the amount of improvement from traditional presentation styles (Vanderbilt, 1990).

Preliminary research in the area of hypermedia indicates some promising directions. It appears that the interactivity afforded by hypermedia environments may positively influence student learning. The work of the Vanderbilt group also suggests that hypermedia environments may provide opportunities for creating meaningful learning contexts.
with which students can interact. Results are, however, only preliminary at this point. As developers are creating more hypermedia environments a fertile area for further research is emerging.

RESEARCH ISSUES AND FUTURE DIRECTIONS FOR HYPERMEDIA

The potential for the use of hypermedia in education is great. Hypermedia systems allow huge collections of information and a variety of media to be stored in compact forms and accessed quickly and easily; thus, diverse and comprehensive materials can be delivered to learners. In addition to large quantities and types of information, hypermedia environments offer learners an opportunity to explore in their own way and learn with their own style; these environments offer learners a type of intellectual freedom never before possible. The characteristics of these environments offer intriguing challenges to researchers.

The initial discussion, development and research in the area of hypermedia has revealed several areas for potential research. Levels of learner control, need for organizers and cognitive maps, information on how students use these environments, and use of hypermedia environments in altering roles of teachers and students are all areas of current interest.

Hypermedia is an enabling environment that offers high levels of learner control. Arrangement of a variety of information delivered through a variety of media frees learners from the usual linear, highly directed learning sequence. Users can follow paths established or recommended by authors or they can design their own paths to explore information. Therefore, hypermedia offers a new way to learn course content, and it also offers challenges in learning how to learn. Students will need to learn how to learn in these open environments. If large amounts of reading and research in the future will be accomplished in hypermedia forms, new strategies to teach these skills may be needed. It may also be necessary to develop new methods to monitor and manage learning in these environments (Marchionini, 1988). Determining effective ways to teach students how to learn in hypermedia environments will be an important research agenda for the future.

In addition to determining effective ways to teach students to learn in hypermedia environments, other learner control issues present a challenge for designers and evaluators of hypermedia environments. Clearly, one of the major goals of the design of such environments should be to give the learner control over the knowledge base and independent access to information (Mega rry, 1988). However, previous research has suggested that the degree and type of control given to the learner may effect student performance. For example, Tennyson and his colleagues (1984), found that adaptive programs (programs that adapt to a learner's needs based on past performance) are superior to programs that give the learner total control. Other studies show that learner control can facilitate intrinsic motivation in students but may be suboptimal in achieving learning outcomes (Allred & Locatis, 1981). Researchers examining hypermedia environments need to further explore the learner control issue.

One specific learner control concern is the tendency for students to become disoriented as they attempt to access the information. Due to the quantity and arrangement of information in a hypermedia environment, it is easy for a user to wander in various directions, lose track of where she/he has been, and become disoriented within the information net. This type of disorientation, as noted by many designers, has been a major shortcoming of hypermedia learning environments (Marchionini, 1988; Heller, 1990). Marchionini (1988) recommended that new layers of organizational structures (for example, a comprehensive index) should be added to help the learner explore a hyperdocument. Heller (1990) recommended that some sort of a map should be provided at the beginning of hyperdocuments in order to provide the learner with an idea of the size and depth of the topic to be explored. Morariu also suggested that "in order to successfully use a hypermedia application, learners must be provided with appropriate and clear navigational and conceptual tools in order to explore even the best-designed systems" (Morariu, 1988). It could be argued, however, that such organizers and cognitive maps could provide too much structure and inhibit the discovery atmosphere of the non-linear hypermedia environment. Clearly, research evaluating types of cognitive maps in hypermedia environments is necessary.

A second learner control concern is the issue of learner distraction. The rich, free learning environment offered through hypermedia may allow students to focus in on information that is not central to teacher learning goals. "Placing an inquisitive, undisciplined young learner in a rich hypermedia environment may be similar to giving a
remote control unit to a student in front of a television with 80 channels of action programming" (Marchionini, 1988, p. 10). Problems of distraction can be discovered by tracing student paths through hypermedia documents and by including appropriate strategies to discourage distraction. These strategies may involve the design of the hyperdocument or they may involve teaching strategies that emphasize avoiding distraction.

Hypermedia tools may provide teachers with an opportunity to create learning environments for students. Because the software used with hypermedia make writing programs relatively simple, the technology allows teachers to create hypermedia documents. Using hypermedia, teachers will be able to adapt instructional materials to individual students' learning styles (Marchionini, 1988). Hypermedia may offer teachers the opportunity to quickly and efficiently create their own hyperdocuments and thus may be the first practical authoring tool for teachers. Measuring the effectiveness of these teacher-made hyperdocuments will offer interesting information to researchers.

Hypermedia offers the potential of altering the roles of teachers and learners and the interactions between them. The nature of hypermedia environments, based on the principles of cognitive theory, grants more control to the learner and encourages the teacher to become a facilitator rather than a deliverer of information. As students work through hyperdocuments, the teacher's role becomes that of guide. The teacher may provide strategies for interacting with the environment and direction in terms of goals for the experience, but the student is given primary responsibility for learning and discovering the material.

The ease of authoring hypermedia documents may also provide an alternative method of communication and assessment for students. Given the tools for working with hypermedia, students can create their own documents. Student term projects might involve creating a hyperdocument on a period in history or on a poem or novel they have read. Observing and measuring outcomes from such student work offers yet another promising research direction.

Finally, hypermedia environments can provide researchers a valuable window with which to observe student learning and learning styles. If hyperdocuments are constructed so that students "leave a track", researchers can gather information on how individual students explored an environment. Given the interest of cognitive psychologists in examining learning processes, the window into these processes provided by the tracks left by a student exploring a hyperdocument will be a valuable tool. This information will be useful to hyperdocument designers and to researchers interested in understanding and defining different learning styles.

SUMMARY AND CONCLUSIONS

Hypermedia is the newest technology receiving attention in the field of education. Through hypermedia environments, students can explore vast quantities of information delivered through varied media; students can explore this information in a non-linear format using their own style. Initial research efforts in the field have suggested that the interactivity afforded by hypermedia environments may positively influence student learning. Early research also indicated that the various mediated approaches afforded by hyperdocuments may help to create meaningful contexts in which students can effectively learn.

Student use of hyperdocuments has opened up several areas of potential research for educators. Levels of learner control, need for organizers and cognitive maps, information on how students use these environments and use of hypermedia environments in altering roles of teachers and students are all areas in need of research.

Educators and researchers seem to agree that hypermedia provides new and interesting possibilities for the teaching/learning process. The extent of the ability of hypermedia to influence student learning has yet to be determined, however.
EDUCATIONAL TECHNOLOGY AND ATTITUDE CHANGE

Introduction

As early as 1931, Thurstone was able to demonstrate the impact of film on the attitudes of children. In this landmark study it was found that two films depicting the Chinese favorably or unfavorably were capable of producing attitude changes in either a positive or negative direction. Since Thurstone's study there have been numerous experiments conducted that have evaluated some aspect of the relationship between educational technology and the attitude formation and change of students. Over two hundred of these experiments were reviewed by Simonson (1987; 1980; Simonson, Thies, & Burch 1979). Generally, the results of those studies were not uniform enough to produce a single, definitive conclusion concerning the relationship between mediated instruction and attitudes. Results were often contradictory. However, there were a considerable number of studies in the literature where researchers were able to produce positive attitude results similar to Thurstone's. In other words, educational researchers reported findings where educational media were used to deliver messages, and desired attitudinal outcomes were produced.

This section attempts to document procedures using media that were successful in experimental situations at producing desired attitudinal positions. These techniques will be supported by citing a sample of specific research studies where the procedure was successfully validated. The following statements are intended as guidelines only, not laws or rules.

Obviously, most instruction is designed to produce cognitive outcomes. Attitude positions are usually of secondary importance when learning processes are developed. However, because attitudes are thought to be predispositions to respond, those attitudinal positions that are related to instructional procedures or content might possibly be important to the instructional developer. Cognitive theory has clearly identified the importance of positive attitudes in learners.

While a positive link between attitude and achievement has been identified by some (Simonson & Bullard, 1975; Simonson, 1987; Levy, 1973; Fenneman, 1973; Perry & Kopperman, 1973; and Greenwald 1966, 1965; for example), most researchers have been reluctant to propose any cause and effect relationship between these two learner variables. Because the relationship between attitudes and achievement has been examined by many, often resulting in unclear conclusions, the reason to be concerned with attitude positions resulting from instruction is not based primarily on the impact of attitude on achievement. Rather, the development of a more favorable attitude toward instruction or subject area is a desirable end in itself. Fleming and Levie (1978) provided additional reasons why the instructional developer should be interested in the attitudes of students. First, most teachers would agree that there are cases when it is legitimate and important to urge learners to accept the truth of certain ideas. In other words, to promote an attitudinal position. Second, as stated above, is that while the relationship between attitudes and learning is unclear it seems to be common sense that students are more likely to remember information, seek new ideas, and continue studying when they react favorably to an instructional method and certain content areas. Last, the educator should be aware of procedures that are likely to influence attitudes in one direction or another so that bias can be reduced when inappropriate. Whatever the reason, attitudinal outcomes should be important considerations for the designer of instruction.

Attitude has been a difficult concept to adequately define, primarily because it has been defined by so many, but also because of its many lay uses and connotations. One of the earliest definitions of attitude was proposed by Thomas and Znaniecki (1918). They defined attitude as "A mental and neural state of readiness, organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations to which it is related" (Thomas & Znaniecki, 1918).

In other words, while attitudes are latent and not directly observable in themselves, they do act to organize, or to provide direction to, actions and behaviors that are observable. Also, attitudes vary in direction, either positive or negative; in degree, the amount of positiveness or negativeness; and in intensity, the amount of commitment with which a position is held (Fleming & Levie, 1978).

Additionally, attitudes have three components: affective, cognitive, and behavioral (Zimbardo & Ebbesen, 1970). The affective component is said to consist of a person's evaluation of, liking of, or emotional response to, some object or person. The cognitive component is conceptualized as a person's beliefs about, or factual knowledge of,
the object or person. The behavioral component involves the person's overt behavior directed toward the object or person.

By applying these definitions and explanations researchers have attempted to evaluate the impact various mediated procedures have had on attitude formation and change.

Design Guidelines

There is a series of research-based procedures that can be considered, and if appropriate, applied, to promote the likelihood of producing certain attitudinal outcomes in learners.

Guideline #1: Learners react favorably to mediated instruction that is realistic, relevant to them, and technically stimulating.

Levonian (1960 & 1962) reported on a study that incorporated the use of a preproduction survey of the target audience to determine their attitudinal positions, among other things, about India. The results of this survey were used as input for the production of a persuasive film on India. Supposedly this approach made the resulting instruction more relevant and realistic to the audience, and this contributed to attitude changes. Tests of hypotheses indicated that desired attitude positions were produced in viewers of the film.

Seiler (1971) found that if persuasive messages were presented by media they were most effective if the visual channel supplemented the verbal through the use of technically relevant graphics or good quality human interest photographs. Klapper (1958) also reported that highly visualized lessons were perceived as more realistic by learners and seemed most likely to produce desired attitudes.

Relevance and realism were examined further by Croft, et al. (1969) and Donaldson (1976). Both reported that "live" messages were the most realistic to learners and were the most effective in producing attitude changes toward intercollegiate athletics and the disabled. Found to be next most realistic and effective were television messages on these topics. Booth and Miller (1974) and Winn and Everett (1978) investigated the realism provided by pictures produced in color versus those only in black and white. They reported a relationship between the use of color, realism, and attitude formation. Color made the images more realistic which seemed to be related to more positive attitudes.

Two additional studies provide interesting information on the correlation between realism and attitude change. McFarlane (1945) found that eight and nine year olds seemed most influenced attitudinally by "story" films rather than "nonstory" films. Ganschow (1970) also reported nonstatistically significant, but important, trends in a study on attitudes toward occupations. It was found that when an actor's ethnic group was the same as a viewer's the viewer identified with the actor, thought the instruction was realistic, and scored higher on attitude-toward-actor's-occupation inventories.

Simonson, and others (1987) reported on a series of studies that seemed to indicate a relationship between media type and attitude change, contrary to what Clark (1983) would predict. Media that conveyed messages most realistically seemed more likely to produce attitude changes. Film seemed better than colored slides, and slides were better than audio. This was probably because the attitudes being changed were very practical ones with which the audience could easily identify (soil conservation and employment of the handicapped), and because of this, realistically depicted messages were the most appropriate and the most persuasive.

While these studies certainly provide far from conclusive support for Guideline #1, they do seem evidence enough to warrant consideration of this idea when attitude outcomes are desired.

Guideline #2: Learners are persuaded, and react favorably, when mediated instruction includes the presentation of new information about the topic.

Levonian's (1960 &1962) studies lend support to the intent of this guideline. When the audience was surveyed about India, it was possible for the developer of the film to use this information to ascertain previous knowledge about India so that new information could be presented. This new information was included to support the attitude position desired by Levonian. Jouko (1972) reported similar results. It was found that the less pre-instruction
knowledge students had about a topic the more attitude change that was produced after an informational and persuasive lesson. In other words, there was a negative relationship between pre-instruction familiarity to topic and attitude change as a result of a persuasive communication.

A similar conclusion was proposed in a study by Knowlton and Hawes (1962). They correlated attitude with knowledge about a topic and found a positive relationship. In this study it was determined that knowledge about a topic was often a necessary prerequisite in order for a learner to have a positive attitude position toward the idea. Stated another way, new knowledge may need to be supplied when attitude changes are desired (e.g. Jouko, 1972), or knowledge may need to be present for a learner to have a favorable attitudinal position toward a topic (Knowlton & Hawes, 1962).

A corollary to Guideline #2 was proposed in a study by Peterson and Thurstone (1933). They reported that younger children were influenced more by persuasive films than were older children. They also found that a series of related films seemed to produce a cumulative influence on attitudes. Possibly, the younger children acquired more new information than the older, more knowledgeable children as a result of viewing the persuasive films, and this contributed to their more significant attitude changes.

It would seem that positive attitudinal outcomes are most likely when the cognitive component of attitude (Zimbardo & Ebbesen, 1970) is considered in the design of persuasive instruction. Level of knowledge is an important variable when attitudinal outcomes are sought.

Guideline #3: Learners are positively affected when persuasive messages are presented in as credible a manner as possible.

Source credibility has been recognized as an important criteria for attitude change since the early 1950s. When mediated instruction is developed it will often be valued positively, and attitudinal positions advocated in the materials will be influential, if the persuasive message is delivered by a credible source or in a credible way. Kishler (1950) found that when the actor in a persuasive film was cast as a member of a highly credible occupational group it was likely that attitude changes advocated by the actor would be produced.

Credibility can also be stimulated by the way material is presented. Seiler (1971) produced three videotaped versions of a persuasive speech on the Vietnam War. It was found that the greatest attitude changes were produced in learners who viewed either technical graphics or human-interest photographs as a part of their visual message, in contrast to a talking-face version. It was concluded that the visuals added credibility to the persuasive argument presented in the speech.

O'Brien (1973) provided additional support for Guideline #3 in a study dealing with the impact of televised instruction on attitude change of rural and urban elementary school students. It was found that urban children identified with television as a method of instruction. Rural students considered a live communication to be most credible. In each case the most credible form of instruction delivered the most powerful attitude change message.

The content of mediated instruction is probably the most critical variable in determining attitude formation and change. If that information is presented logically, and intelligently (i.e., credibly) it is likely that it will be favorably received and will be persuasive.

Guideline #4: Learners who are involved in the planning, production, or delivery of mediated instruction are likely to react favorably to the instructional activity and to the message delivered.

Active involvement in the learning process was examined as a component of several research studies. Erickson (1956) found that students who actually produced a film on science concepts reacted more favorably toward instruction and toward science than did students who only watched science films. Coldevin (1975) involved students in message delivery through the use of various review and summarization techniques that were part of an instruction sequence. It was found that short reviews after TV lesson sub-units produced the most favorable attitude reports in students. Simonson (1987) conducted an experiment where students were convinced to make counter-attitudinal videotapes without realizing that attitude change was the primary purpose of this activity. The process of
involving subjects in the making of these videotapes was found to be successful in producing significant attitude changes in subjects.

Microteaching is an involvement technique that has been found by many educators to be successful in changing attitude positions of preservice teachers. One study that evaluated the impact of microteaching in a somewhat controlled situation was conducted by Goldman (1969). It was reported that microteaching produced significant attitude change toward self in college females.

All other things being equal, it would seem that in the affective domain the active learner perceives instruction and information more favorably than does the passive learner. Student involvement is an important technique for promoting desirable attitudinal outcomes.

Guideline #5: Learners who participate in post-instructional discussions and critiques are likely to develop favorable attitudes toward the delivery method and content.

A powerful technique for promoting favorable attitudes which was evaluated by several researchers consisted of the addition of follow-up discussions to the instructional sequence. These follow-ups usually involved learners in an analysis or critique of the instruction and message presented. Allison (1966) found that only when post-viewing discussions were included, after students watched motivational science films, did significant attitude changes occur. Fay (1973) reported similar findings in a study which used follow-ups to a film on the problems of the handicapped and the need for "barrier-free" buildings. Attitudes toward continuing education were significantly altered after classroom teachers saw a film and participated in a discussion on the subject. This study was conducted by Burrrichter (1968).

An interesting variation to the studies reported on in the previous paragraph was conducted by Domyahn (1972). In this experiment, students viewed a nonpersuasive film on the responsibility for the fall of Eastern Europe to the Communists after WWII. Domyahn reported that attitude changes were produced only in the treatment groups that participated in persuasive critiques after viewing the film.

Guidelines #4 and #5 are directed toward the behavioral component of attitude. When learners are involved in the instructional situation it is likely that they will value the learning process positively and will maintain or develop favorable attitudes toward the content presented. Again, it is important to remind the reader that these guidelines are only recommendations, and in a given situation may not be as effective as indicated by the results of the studies reported above.

Guideline #6: Learners who experience a purposeful emotional involvement or arousal during instruction are likely to change their attitudes in the direction advocated in the mediated message.

Janis and Feshbach (1953) presented a slide/audio tape program on the effects of poor dental hygiene to high school students. They varied the intensity of a fear-arousing appeal in three versions of the presentation to determine the most influential delivery technique. All three methods were successful at producing aroused, affective reactions in the students. However, it was found that a minimal fear-arousing appeal was most successful in modifying attitudes because the stronger versions left students in a state of tension that was not alleviated by the remedies offered during the slide show. Janis and Feshbach concluded that strong, fear-producing appeals were not as effective at changing attitudes as were more moderate appeals because the audience became motivated to ignore the importance of the threat to reduce the tension they felt.

Rogers (1973) reported on a study that supported this position. Public health films dealing with cigarette smoking, safe driving, and venereal disease were tested in three different studies. It was found that the more noxious the film, the more fear was aroused in the viewer. However, it was also reported that these fear-arousing films were most effective in changing attitudes when preventatives or statements of probability of exposure to the malady discussed in the film were included as part of the motion picture.

Lamb (1987) conducted a study using a computer lesson to change attitudes toward using seat belts. She found that when a lesson included a segment that attempted to arouse students emotionally about the possibility of death or injury from an accident it was more successful at changing attitudes than was an almost identical lesson that did not have the fear producing section. Simonson, and others (1987) reported on a similar study that used video to deliver
fear producing messages about the consequences of smoking. It was found that when the fear producing scenes were followed by scenes that gave viewers information about how they could stop smoking, the persuasive messages were more successful than were the scenes in the treatment that showed only sick and dying smokers.

Miller (1969) examined the degree of emotional involvement produced in viewers of motion or still picture versions of the same script. It was reported that the motion picture version produced the higher positive evaluation by students. Miller concluded that this was because of the increased involvement in viewers of motion pictures.

Again, the studies supporting Guideline #6 indicate that viewers' participation in the learning process is important when attitudinal outcomes are desired. In these cases involvement was emotional, rather than behavioral, as it was in the studies cited to support Guidelines #4 and #5. It would seem that learner involvement is a powerful technique to use if attitudinal outcomes are to be an important consequence of instruction.

Summary and Conclusion

Attitudinal outcomes should be a concern to the developer of teaching materials. Techniques likely to produce a favorable reaction in students should be identified, refined, and evaluated routinely as a part of the instructional process. It was readily apparent after studying the guidelines and research summarized previously, that the type of media was only one of a number of variables that were found to influence attitudes. Media were primarily carriers of information in these studies. There was no best medium found for producing attitudinal outcomes. However, there probably is a best approach for the development of instruction that will maximize the likelihood of desirable attitudes being fostered in learners in a given situation. By critically applying the general guidelines listed above, the instructional developer should be well on the way to promoting attitudinal positions in students that are likely to contribute to a healthy, positive learning environment.
SUMMARY AND CONCLUSION: RESEARCH, THEORY, AND EDUCATIONAL TECHNOLOGY

Introduction

It is curious to read the large number of recently published studies that advocate the superiority of a particular medium when research clearly indicates that no one medium is inherently better than any other. Most recently, advocates of computer based learning have made claims concerning the superiority of the computer. Of course, as Clark (1983) says, conclusions about the real impact of media on learning are disseminated slowly and must compete with the advertising budgets of a multimillion dollar industry which has a vested interest in selling machines for instruction. Also of impact are the high expectations that most people have for technology. Technologies have revolutionized industry and many educators have hoped that they would do the same for education. The computer, considered by some as the ultimate medium, brings to a peak the hopes and expectations of many educators. This is not necessarily inappropriate. Rather, the desire that many have for an improved educational process based on the widespread application of technology should be realistic. The evidence shows that a media-based teaching and learning process is not inherently better than traditional teaching and learning processes. However, the evidence supports the position that technology based teaching and learning is effective. That is, people can learn from media and because of the improved instructional strategies and the enhanced materials, facilitated by media, they may learn more effectively and in some cases, more efficiently.

This concluding section has two sub-sections. First, there will be a summary of what the research tells us. Second, recommendations for future research directions in educational technology will be proposed.

Summary of the Research: What it Tells Us

If a reader of this monograph was limited to remembering only one idea from it, then Clark's "...mere vehicles..." analogy would be the authors' choice for the most significant concept provided by the literature. Educational technology provides ways of efficiently and effectively storing and delivering instructional messages; however, the technology, in and of itself, does not directly impact learning. Rather, educational technology can facilitate the teaching and learning process and potentially make education richer and more stimulating by creating environments and presenting content not possible otherwise.

Once it is widely understood that there is no superior medium, researchers and practitioners can concentrate on the important questions of instructional design and effective methodology. Understanding the learner and the process of organizing instruction are the critical issues of educational technology. The theories discussed earlier in this paper (systems, communication, behaviorist, cognitive), never suggested the superiority of one medium. Rather, they provided and still provide, an overview for investigating the teaching and learning process when media are involved. Specifically, behaviorism and cognitive theory contribute information about the characteristics of learners and the learning process. Systems and communication theory give insights into the process of message construction, delivery, and organization.

The goal of a "true" education, as Cronbach and Snow (1977) have stated, is to accommodate the individual by tailoring instruction to his/her needs. The development of instructional technologies has made possible this accommodation; however, the best uses of technology and most appropriate instructional strategies to be employed with the technology are just beginning to be identified.

Research on different instructional media (audio, still pictures, film, television, and computers) has indicated production and utilization techniques that may be effective in facilitating learning, and researchers have examined the effectiveness of media when used to enhance the academic achievement of groups. The evolution of educational technology research (from media comparison studies to intra-medium and aptitude treatment interaction studies) points toward a more focused examination of media effects on learning.

Specifically, the reviews in this paper indicate several significant findings for educators. These include:

• The paradigm shift from behavioral to cognitive psychology has effected technology research in the following ways:
  1. Emphasis on outcomes involving problem solving and process skills.
2. Emphasis on using technology to create meaningful learning contexts where students are actively involved.

3. Focus on the interaction of specific technologies with specific learner characteristics.

- Future research in educational technology should use intra-medium, aptitude treatment interaction or naturalistic designs; some evaluation research is also necessary.

- Media comparison studies are usually inappropriate.

- Students can learn from all educational media; there is no best medium.

- Computers and technology can be used to help students learn new material in new ways; these types of uses must be encouraged and evaluated.

- In general, teachers and schools are not yet integrating newer computer applications into the curriculum.

- Gender differences related to computer use and attitude exist.

- Persuasion is possible using mediated messages. Attitudinal outcomes can be produced as predictably as cognitive outcomes.

- Computers are increasingly being interfaced with other technologies to create learning environments for students; the computer should no longer stand alone as the technology for researchers.

- Hypermedia environments provide potential for creating meaningful, relevant learning contexts for students.

Recommendations for Future Research

By critically looking backward, it is possible to set the agenda for the future. The following recommendations are directions for this decade and are derived from past research and practice.

- Use findings from audio, still picture, video, film and computer-based learning research as a foundation for research on hypermedia.

- Examine the use of technology-based environments to improve students' higher order thinking and problem solving skills.

- Develop and use outcome measures to assess higher order thinking and problem solving skills.

- Develop evaluation methods to assess the cognitive processes employed by students to achieve instructional goals.

- Continue to examine methods of using technology to improve the teaching of writing.

- Examine the use of technology in the restructuring of schools; that is, in changing the roles of students and teachers, and the organization of classrooms.

- Develop and examine interventions designed to encourage females to use technology and develop positive attitudes.

- Examine the instructional dynamics of distance education environments from the learners' perspective.

- Examine the instructional strategies to be employed in distance education as well as teacher training issues.

- Design and perform appropriate cost-effectiveness studies.
• Examine methods of using technology to create meaningful and realistic instructional contexts.

Finally, it is again appropriate to quote Mary Alice White, "What we need to do, then, is to educate as though this technological revolution is what it really is--the third learning revolution--the most important change in learning since the 16th Century" (p. 63).

Now that researchers are free from questions of which form of technology is best, they can concentrate on discovering the most effective means of using technology to facilitate learning. Results and directions cited in this paper give credence to White's claim that modern technology, appropriately used, can facilitate the third learning revolution. Researchers in technology have begun to ask the questions which will enable this revolution to restructure schools in ways that will: Adapt curricula to individual learner characteristics, make learning more active and meaningful for all students, and help students and teachers learn how to learn.
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## Comparison of Behavioral and Traditional Cognitive Theories of Learning and Cognition

<table>
<thead>
<tr>
<th>Behavioral learning theory</th>
<th>Traditional cognitive theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Learner is seen as passive and reactive to environment.</td>
<td>1. Learner is seen as active and mastering the environment.</td>
</tr>
<tr>
<td>2. Learning occurs because of associations among stimuli or between stimuli and responses.</td>
<td>2. Learning occurs because the learner actively tries to understand the environment.</td>
</tr>
<tr>
<td>3. Knowledge consists of whatever pattern associations have been learned.</td>
<td>3. Knowledge consists of an organized set of mental structures and procedures.</td>
</tr>
<tr>
<td>4. Learning is the acquisition of new associations.</td>
<td>4. Learning consists of changes in mental structure brought about by mental reasoning.</td>
</tr>
<tr>
<td>5. Prior knowledge influences new learning primarily through indirect processes, such as positive or negative transfer because of similarity of stimuli between situations.</td>
<td>5. New learning is based on using prior knowledge to understand new situations, and changing prior knowledge structures to deal with new situations.</td>
</tr>
<tr>
<td>6. Discussion of the activities of the mind is not permitted.</td>
<td>6. Discussion of activities of the mind is the central issue in psychology.</td>
</tr>
<tr>
<td>7. Strong experimental research tradition. Theories can only be verified through experiment.</td>
<td>7. Weak experimental research tradition. Observational research, thought, experiments, and logical analysis can be used.</td>
</tr>
<tr>
<td>8. Education consists of arranging stimuli so that desired associations are made.</td>
<td>8. Education consists of allowing/encouraging, active mental environments.</td>
</tr>
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</table>
Figure 1

DOMAIN OF EDUCATIONAL TECHNOLOGY

Educational Management Functions

Organization Management

Personnel Management

Educational Development Functions

Research-Theory
Design
Production
Evaluation-Selection
Logistics
Utilization (Utilization/Dissemination)

Learning Resources

Message
People
Materials
Devices
Techniques
Settings

Learner
STAGE I: SYSTEM DEFINITION

FUNCTION 1: IDENTIFY PROBLEM

FUNCTION 2: ANALYZE SETTING

FUNCTION 3: ORGANIZE MANAGEMENT

STAGE II: SYSTEM DEVELOPMENT

FUNCTION 4: IDENTIFY OBJECTIVES

FUNCTION 5: SPECIFY METHODS

FUNCTION 6: CONSTRUCT PROTOTYPES

STAGE III: SYSTEM EVALUATION

FUNCTION 7: TEST PROTOTYPE

FUNCTION 8: ANALYZE RESULTS

FUNCTION 9: IMPLEMENT/RECYCLE
Figure 5  Aptitude Treatment Interaction Example

Figure 6  Aptitude Treatment Interaction Example
The Dick and Carey Systems Approach Model for Designing Instruction