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Educational technology : a review of the research

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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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1993
EDUCATIONAL TECHNOLOGY:
A Review of the Research

by
Ann D. Thompson
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Constance F. Hargrave

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
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 Log 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.