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ABSTRACT

Noting that cognitive science has developed a number of theories relevant to learning and the development of thinking skills, this paper contains an attempt to broaden the limited application of cognitive science by developing four distinct categories of applicable cognitive theories for multimedia instructional design. The paper summarizes the four categories (organismic developmental, information processing, behavioristic, and contextualistic) to provide a more complete foundation from which to select an appropriate design philosophy. The paper then addresses how certain design features may appear in the context of computer-assisted instruction when built around the various cognitive theoretical stances. The paper concludes that contextualism (which incorporates the individual, the environment, and the system acting one upon the other) appears to hold the greatest promise for future research. (Contains 49 references.) (RS)

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Applying Cognitive Theories to Multimedia Instructional Designs

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Abstract

Applying cognitive theories to multimedia instructional design

Cognitive science has developed a number of theories relevant to learning and the development of thinking skills. However, within instructional design, the limited application of cognitive science typically has incorporated only information-processing theory. This paper contains an attempt to broaden this current state by developing organismic developmentalism, information processing, behaviorism, and contextualism as four distinct categories of applicable cognitive theories for multimedia instructional design. Finally, a recommendation to consider contextualism as offering the greatest future potential for instructional design is presented.

Applying cognitive theories to multimedia instructional design

Cognitive science and multimedia instructional devices share a common link in their evolutionary development--computer technology. Not until the development of computer processors that could organize and assemble input data into other usable forms did the revolution in cognitive science truly bloom (Coulter, 1983; Gardner, 1987; West, Farmer, & Wolff, 1991; Siegler, 1983). In the same way, the use and study of multimedia devices to facilitate the learning process in more unique and flexible ways did not mature until information sciences provided the necessary mechanisms and frames.

The history of instructional design can be traced to a three-fold integration of instructional social science theory, information science pragmatics, and management science and engineering (Johnson & Foa, 1989). However, the intimate association between information processing and instructional design has created a situation where many, if not most, of the individual researchers working in instructional design have adopted a philosophical orientation that is derived directly from information processing theory (e.g. Marzano, Brandt, Hughes, Jones, Presseisen, Rankin, & Suthor, 1988; Spiro & Nix, 1991; West, Farmer, & Wolf, 1991). As a response to this current state, the first portion of this essay summarizes the diverse theoretical themes from cognitive science, including information-processing theory, in order to provide a more complete foundation from which to select an appropriate design philosophy. Following this section, a series of applied constructs derived from the various cognitive science theories are extended for instructional design.

Cognitive Science Theory

Cognitive science theory that addresses individual development can be broken down into at least four distinct perspectives: 1) Organismic Developmental, 2) Information

processing, 3) Behavioristic, and 4) Contextualistic (Rebok, 1987). Even though there are numerous individual cognitive development theories espoused, the basic premises of most are derived from these basic categories. Some theories may be assigned clearly to a single category; others may be composites of selected concepts from several categories. The following is an explanation of these various perspectives and the associated theories and theorists that represent these perspectives.

Organismic Developmental Perspective

Within this perspective, the concept of genetic epistemology is a major premise for cognitive development. In other words, the human organism establishes knowledge through the emergence of certain relationships between the known (the environment) and him or herself (Leiser & Gilleron, 1990).

The individual most closely identified with organismic developmental perspective is Jean Piaget. For Piaget, cognitive development was a series of biological adaptations to the existing environment that resulted in an a psychological equilibrium. Shifting in intelligence caused by these adaptations was termed equilibration. Piaget argued that all significant cognitive developmental advances resulted from some form of equilibration. For example, a small child views a single piece of food as one but when the parents of that child cut the food into pieces the child conceptualizes more food, not the same amount divided into smaller pieces. Later on in development, the child will gradually begin to grasp that the quantity is the same. Thus, equilibration becomes a fundamental concept for Piaget's theory of cognitive development (Piaget, 1929). Of similar importance to this theory is Piaget's description of intelligence; he postulated two inherited intellectual functions--organization and adaptation.

Piaget theorized that human organisms organize cognitive functions by dividing the

intellectual regime into meaningful systems of psychological activity. Higher-order organizations were thought to permit more effective interaction with the outside world. Organization, then, became a measurable construct for Piaget leading to an analysis of where the individual organism is at in the developmental process.

Adaptation, by contrast, is a continual process regardless of the stage of development and is broken down into two elements--assimilation and accommodation. Both constructs deal with environmental interactions. Assimilation refers to organisms using preexisting psychological organizations to interpret the environment. Whereas, accommodation refers to the tendency for one to modify the preexisting internal organizational structures to account for additional information.

As can be implied from the basic elements of this organismic developmental theory, Piaget believed that all human organisms go through very distinct and identifiable stages of development. Piaget established four major periods (sensorimotor, preoperational, concrete operational, and formal operational) each of which had a number of identifiable substages of intellectual activity or schemes.

Piaget's theory has resulted in a large number of critics (e.g. Coulter, 1983; Fischer, 1980; Siegel, Bisanz, & Bisanz, 1983) as well as an equally large number of supporters (e.g. Dasen, 1972; Elkind, 1981; Flavell, 1963,1985; Greenfield, 19 , Kuhn, 1978). Some research points to the fact that preschoolers and infants know more than what Piaget suggested (Gelman, 1979). Other research suggests that Piagetian researchers should forgo the all-inclusive stage notions and go to domain-specific descriptions (Fischer, 1980). Though Piaget's influence has diminished somewhat over the years, his theory is still incorporated by a number of educators and researchers in cognitive science (Rebok, 1987).

Another organismic developmentalist is Heinz Werner. Similar to Piaget, he

suggested that individuals go through specific stages of development. The general premise for Werner's theory is orthogenesis. Werner states that organisms have "a tendency to move from a state of relative globality and undifferentiatedness towards a state of increasing differentiation and hierarchic integration" (Werner, 1957, p. 126).

According to Thomas (1985), Werner's theory is not completely novel. He traces the theory to Charles Darwin and the psychologists looking at primitive peoples in the late 19th and early portions of the 20th centuries. Werner thought orthogenesis could account for the complexity differentiation found in the different peoples. He extended this orthogenetic principle to four aspects of development.

Werner's theory states that individuals go from a syncretic, rigid, diffuse, and unstable state to a discrete, flexible, articulate, and stable one. The more cognitively complex the individual, then the more these end states will be realized. These concepts form the foundation of Werner's theory.

Langer (1970) took these principles and divided the stages of development as suggested by Werner into the following three categories. Sensorimotor Development, Perceptual Development, and Contemplative Development. Unlike Piaget, Werner did not attach specific ages to these developmental stages, but they are quite similar with respect to expected observations.

Jerome Bruner is another organismic developmentalist that draws heavily on Piaget and Werner, but in spite of the close ties, Bruner differs in some significant ways. Like Werner, Bruner's model of cognitive development is broken down into three stages. However, Bruner's stages of development are significantly different in the labeling and the concept behind what drives the stages. The three stages are labeled as Enactive, Iconic, and Symbolic. In other words, individuals go through stages of representation of the outside

world in terms of actions perceived, images available, and finally, symbols or language systems employed (Bruner, Olver, and Greenfield, 1966; Bruner, 1973). Bruner sees the development of language as a major factor in the emergence of complex thinking skills. Piaget, by contrast, viewed language as a consequence of changes in cognitive skills.

An interesting aspect of the previous theorists is that all concentrated their efforts on children with the presumption that adults can attain no new stages of development (Flavell, 1970). In response to this, K. Warner Schaie has developed a developmental model of cognition that extends into the adult years. Primarily an extension of Piagetian theory, Schaie states that adult cognitive development involves acquisition, achievement, responsibility, execution, and reintegration (Schaie, 1977/78). The terms used to describe Schaie's stages are indicative of what takes place within the stages. Thus, Schaie views accommodation and assimilation as described by Piaget as augmented by the environment that adults would experience as opposed to children. Though Schaie is not purely organismic in focus, all of the stages can be linked to physical processes of life.

Several other theorists have suggested organismic developmental theories that address cognition indirectly. The most prominent among these are Erikson (1963, 1968), Freud, and Kohlberg (1976, 1978). Although there may not be extensive application of these theorists to educational practice, they provide an alternative with which to discuss adulthood, sexuality, and morality as portions of the cognitive domain, as opposed to distinct separations of several domains.

Information-processing Perspective

Stillings et al. (1987) refer to cognitive science as the marriage between cognitive psychologists and computer scientists. Consequently, the computer functions as the metaphor for the human thinking process in much of what is termed cognitive science

theory. Lachman, Lachman, and Butterfield (1979) state that the major objective of the information-processing approach is to trace the flow of information across space and time through an identifiable system. The initial modeling of this system can be traced back to Atkinson and Shiffrin (1968) (Leahy & Harris, 1989). Researchers in cognitive development did not take long to recognize the advantages of such a model (Siegler, 1983). Rebok (1987) comments on the benefits of such an information-processing system.

> The approach offers a generally appealing metaphor of the human being as a limited capacity symbol manipulator. People set goals; processing limitations hinder the goals' attainment; and people develop memory strategies such as rehearsal, organization, and elaboration to overcome the limitations. Overall, this sequence seems to capture closely how humans go about knowing the world. (p. 44)

In addition, information processing offered to those studying cognition a precise descriptive vocabulary. Input, output, serial processes, parallel processes, sensory memory, working memory, long-term memory, encoding, retrieval, pattern recognition, and attention are but a few of the significant terms utilized by the information-processing approach to describe human cognitive development.

Information processing seems to have gained momentum after Newell & Simon (1972) incorporated information processing as a frame with which to explain the process of human problem solving and as a potential design for artificial intelligence for the future. They differentiated between the unclear and vague goals (fuzzy problems) and precise goals (sharp problems). This added utility to the modeling of Atkinson and Shiffrin (1968).

Essentially, what information processing suggests is that stimuli enter the brain through a variety of input mechanisms (sensory organs). This input is placed into a sensory memory which lasts anywhere from 0.5 seconds to 4 or 5 seconds, depending on the input

mechanism (Sperling, 1960; Darwin, Turvey, & Crowder, 1972). The visual images that last in the sensory memory are termed icons (again, a reflection of the influence of computer terminology on cognitive science); those auditory sounds that persist in sensory memory are termed echoes. Once these icons and echoes (along with other remnants of sensory perceptions) have been placed into the sensory memory the images either gather the attention of the individual, cue a pattern recognition response, or decay unused. This process of drawing attention and pattern recognition is of particular significance to developmentalists.

Once the information is processed through one of the previously named functions, it enters into the second memory store--working memory (also known as short-term memory, active memory, primary memory, etc.) This memory store functions as the working consciousness according to information-processing theorists. This storage area is continually utilizing information that is very transient in nature and can only be retained through rehearsal procedures on the part of the individual. One of the key factors associated with the working memory is the concept of the storage area having a limited capacity.

Miller (1956) demonstrated that in repetitive digit-span tasks that the capacity of individuals was 7 ± 2 numbers. Brown (1958) and Peterson and Peterson (1959) demonstrated in their studies that the working memory has a useful life of 15 to 30 seconds without rehearsal. These early studies helped give more credibility to the information -processing approach by providing concrete parameters for memory storage, similar to computer storage devices currently in use.

As a re[illegible]lt of illuminating the impermanent nature of the working memory, researchers found that Miller's (1956) bits of information could vary widely in size and could vary in the nature of the memory (see Leahy & Harris, 1989). A memory could be visual, auditory, or sets of [illegible] is other types of symbolic representations. The process by which an individual

could store these several pieces of distinct data was termed chunking. Thus, the information-processing approach suggests that a person could store very large amounts via chunking and could retain that information indefinitely if those chunks were rehearsed, either in a maintenance or an elaborative process.

Maintenance rehearsal would simply keep the information in the working memory until the information had been used. Elaborative rehearsal would connect the information with other information that had been located in the permanent or long-term memory store through a process of encoding and retrieval. The eventual result would be the inclusion of this information in long-term memory, as well. Some researchers in cognitive science have used these rehearsal practices to explain the primacy effect of the serial position curve (the curve plotted along axes of time and information recalled that demonstrates people remember items from the first and last portions of a presentation better than information placed in the middle) (see Leahy & Harris, 1989).

Once the rehearsed information has reached the long-term memory, theorists have identified at least two subdivisions of the storage area. Tulving (1972) was the first to label long-term memory as being comprised of episodic and semantic memory. While semantic memory is all the general information that we store, episodic memory concerns specific events surrounding key points of recall.

Since Tulving's work, others have stated that the two categories of long-term storage are inadequate. Rubin (1986) has differentiated episodic memory into personal experiences and experimental experiences. Brewer (1986), likewise, has suggested an intricate taxonomy of memory along four dimensions. The dimensions are types of input (ego-self--personal memory, visual-spatial--for objects and places, visual-temporal--for events and actions, semantic--facts and knowledge) bound by the form of representation (imaginal or

nonimaginal) and the conditions of acquisition (single or repeated).

Consequently, in the process of assigning information to one of these two broad categories of information and then into one of the finer subdivisions of these categories of storage, the input must go through a process of representation. In other words, information in long-term storage must be represented by some identifiable memory unit. Information-processing theorists label the forms the memory unity may take as either analogue or analytic. Analogue representations, as the name implies, closely resemble what it represents. Analytic representations are entirely abstract and arbitrary

One process of converting this information into analogue representations is imagery A dated concept, imagery was revived as a psychological concept and has developed and maintained a strong research base since the 1960's (see Marschark, Richman, Yuille, & Hunt, 1987). This concept is often referred to as "pictures in your head." Although helpful, the metaphor constrains the idea of imagery since imaging has a high degree of adaptation and plasticity. Imaged memory units can be made to move, change, and anticipate things never seen. Imaging may be an important link in the role of memorization.

Paivio (1971) found that concrete terms were easier to recall than abstract terms and has proposed the dual-coding theory. That is, concrete terms have a ready store of sensory images with which to attach to the term, thereby making those terms easier to place into long-term storage. Abstract terms, since they have a much smaller store of possible sensory images, are less efficiently coded by the mind-brain.

Related to imaging is a concept that has found considerable favor with cognitive scientists--cognitive mapping. Lynch (1960) established the precedent by describing mental maps in terms of <u>paths</u>, <u>edges</u>, <u>districts</u>, <u>nodes</u>, and <u>landmarks</u>. Paths generally indicate channels for people to travel, edges refer to borders, districts are areas with common

identifying features, nodes are significant focal points, and landmarks are points of reference. Cognitive maps are usually oriented around some useful grid or axis. Though Lynch's description principally concerned how people remember how to get from place to place, others have extended cognitive mapping beyond traditional maps and have applied mapping to other memory tasks, as well.

Another class of memory models is centered around the existence of nodes. These models are referred to frequently as network models of semantic memory. The earliest writers that proposed a semantic network model, Collins & Quillian (1969), suggested that the nodes are arranged in subordinate and superordinate hierarchies. Each node is thought to assign attributes to a bit of information.

However, linguists in cognitive science have attempted to explain troublesome problems for a simple network model and have added the feature comparison model of semantic memory (Smith, Shoben, and Rips, 1974). This model suggests that the nodes of long-term memory have a list of concepts that are common attributes of the information. Smith et al. suggested that each list of attributes have defining and characteristic features. This model helps explain the typicality effect, where it takes longer to verify truth statements about category membership of less typical instances (as in determining whether a salamander or a lizard is a category of reptile, etc.). However, this approach is limited in its explanation of meaning flexibility.

Schoen (1988) argues that all models of semantic memory must address the phenomenon of meaning flexibility. Apparently, individuals are able to draw on a particular 'shade' of meaning when a word is presented in the appropriate context. This presents a problem for most models of semantic memory since most are aligned in linear networks or checklist approaches to understanding. Thus, meaning flexibility is still an important

construct for consideration in theory adoption.

In an attempt to begin explaining the complexity of the memory and cognition process, McClelland and Rumelhart (1986)(also see Rumelhart & McClelland, 1986) have presented a frame for what they term parallel distributed processing (PDP) models. These models recognize that cognitive processes can be done simultaneously (parallel) and are distributed across and extensive network. Though similar in structure to the earlier network models, the PDP models do not suggest hierarchical orientation of the units of information. Additionally, the PDP or connectionist models do not assume that the units of information represent meaningful data, rather the information is presented in a subsymbolic form and the PDP models suggest patterns of activation or inhibition. These patterns will lead to the retrieval or encoding of information for use or storage.

As can be suggested from the various proposed models for long-term memory storage, there are a number of proposed methods through which one can insert and/or recall information for future use. Consequently, in order to know which of these methods is useful there must be a system of measuring memory functions.

Traditionally, recall and recognition chores have been the usual tests employed by educators and psychological experimenters alike. Recall may be in free or cued forms; recognition may be in yes-no/old-new or in forced choice forms. Both recall and recognition are helpful in establishing explicit memory function; however, Schacter (1987) concluded that a significant aspect of memory has been left unexplained. That feature is implicit memory.

Implicit memory differs in that it is employed in tasks that indirectly reveal memory function such as identifying objects or words with partial clues, whereas explicit memory (recall/recognition) directly reveals memory function. Schacter (1987) discovered that the

data between the explicit and implicit memory tests were inconsistent. This discrepancy suggests that certain underlying dimensions of memory may yet yield a better understanding of how to retrieve and encode information for storage and usage.

As can be inferred from the previous section, information-processing theorists have developed a complex and involved system that has only been summarized here. However, this involved system is not without critics. Many in cognitive science have noted how the information -processing approach deals primarily with cold cognitive functions, i.e. emotion and affect are avoided as an entirely different domain (e.g. Feezel, 1985). Consequently, those interested in applying cognitive science theory to practice must look at other alternative explanations for cognitive development and function.

Behaviorism

Possibly the earliest theories to develop in cognitive science (before it was known as cognitive science) came out of traditional behaviorism. Guthrie, Hull, and Tolman set the stage in developing explanations for learning based on a behavioristic philosophy. Essentially these early researchers reduced learning to a series of stimulus-response (S-R) chains. This reduction of learning to a series of S-R chains has been termed elementarism and is a principle component of behaviorist theory. However, the early behaviorists were severely chastised for ignoring empirical evidence. As a response, B. F. Skinner began a series of what he termed scientific experiments to determine what would be the most efficient way to learn based on the principle of conditioning. Skinner developed experiments that were strictly for use with animals. However, Skinner strongly believed that the performance of the animals would lead scientists toward a better understanding of human cognition as well. Basically, Skinner believed that with the proper incentive, creatures of all types could be trained to do various tasks (learning in Skinner's view) (Skinner, 1974). Unfortunately,

Skinner never had the opportunity to attempt his procedures with human subjects and his notions of conditioning and reinforcement could never be tested. However, it did provide a springboard for other behaviorists.

Within education, one individual that has promoted behavioral cognition has been Robert Gagne` (1977). Gagne` proposed what he termed the cumulative learning model. He posited a hierarchy of learning processes from simple S-R responses to complex rule learning and problem solving. He proposed a sequence that developed beginning with S-R connections, these extended into S-R chains, once chains were able to be assembled the individual could go on to verbal associations, these in turn lead to discrimination; ultimately, the individual could process complex concepts and rules together to complete complex problem-solving tasks. Although the relationships are likely more complex than Gagne` proposed, the general progression that he offered holds up to most comparisons (Rebok, 1987).

Another behaviorist cognition theory that has generated a good deal of research has been the social learning theory of Bandura (Zimmerman, 1983). Bandura proposed that in learning an individual passes through a series of procedures that begin with a modeled event. This modeled event leads the individual to attend to the event, key stimuli is transmitted, and observation of the stimuli ensues (attentional process). Bandura then suggested that the information goes through a process of symbolic coding, organization, symbolic rehearsal and then motor rehearsal in a phase termed the retention process. Once retained the individual is said to test his or her ability by experimenting with physical capabilities to match the action, check the availability of component responses, and self-observation and accuracy feedbacks; all of which takes place in the motor reproduction processes phase. Finally, the individual passes though a motivational process stage that entails eternal

reinforcement, vicarious reinforcement, and self-reinforcement. All of these phases will ultimately lead to matching the performance of the modeled behavior.

One of the advantages of the behaviorist approach to cognitive theory is the fact that theories such as Bandura's and even Skinner's deal more with the hot side of cognition--affect and emotion--than either organismic developmental or information processing. The obvious disadvantages are that the behaviorists reduce all learning to a series of incremental S-R type transactions that form an elementarism that disavows jumps in learning and makes self-discovery somewhat difficult to explain.

Contextualism

An approach that is gaining widespread acceptance and generating a large amount of discussion is the contextual approach to cognitive developmental theory. Labouvie-Vief and Chandler (1978) comment that the contextualistic perspective views the area of cognitive growth as a process that evolves from multidirectional sources of complex interactions between an individual that is constantly undergoing change and an environment that is doing likewise. Hence, the overall conclusion or guiding principle is that there is no fixed or absolute end state to this process of cognitive development.

The individual that has contributed the most to this perspective died more than forty years ago, but whose work has seen an enormous surge in applied research in the past decade. Lev Semenovich Vygotsky, a Russian psychologist from the first half of this century suggested an approach to cognitive developmental psychology that concentrated on the how and where of cognitive growth. In an attempt to combat biological reductionism and the mechanistic behaviorism, Vygotsky suggested that no one criteria can be used as a measure of stage developmental growth because of the inherent complexity of the overall process.

At the core of Vygotsky's theory is the notion of mediation between natural-psychological and cultural-psychological development. An individual is forced to reformulate an explanatory framework for understanding the world, not abandon or replace this framework. Consequently, mediation takes place within the individual (internalization) and the process of the reformulation forms the foundation blocks of cognitive development.

Vygotsky differentiated between higher and lower mental functions using the locus of the mediation control as the determining factor. In higher functions the stimulation for the control of regulation is from within the individual, by contrast, lower mental functions rely totally and directly on outside environmental stimuli (Vygotsky, 1978).

Another differentiating characteristic is in the ability of the individual to have a conscious realization of the intellectualization of a situation. Being able to reflect on the situation provides a means through which the individual is forced to mediate between what is being observed and what is being processed through the mind. This self-reflection on thinking is termed metacognition.

Third in Vygotsky's differentiation taxonomy is the social nature and origin of the mental functions. Vygotsky argues that the "transition from a social influence external to the individual to a social influence internal to the individual" (Vygotsky, 1960, p.116) is at the very core of the developmental process.

According to Wertsch (1985), Vygotsky's genetic method to studying cognitive development (i.e. genetic in the sense that it begins at the inception of a formative process) can be summarized in five fundamental axioms.

1. Human mental processes must be studied by using a genetic analysis that examines the origins of these processes and the transitions that lead up to their formation.

2. The genesis of human mental processes involves qualitative revolutionary changes as well as evolutionary changes.

3. Genetic progression and transitions are defined in terms of mediational means (tools and signs).

4. Several genetic domains (phylogenesis, sociocultural history, ontogenesis, and microgenesis) must be examined in order to produce a complete and accurate account of human mental processes.

5. Different forces of development, each with its own set of explanatory principles, operate in the different genetic domains.

(pp.55-56)

These five principles form the core of Vygotskian psychology and his theory of cognitive development.

Researchers in this contextualist tradition have both criticized and found support for the designs of Vygotsky's theory. The specific operationalizations of the theory include the zone of proximal learning (location of internalized metacognition), semiotic mechanisms (devices which mediate the changes on the interpsychological plane and show up as change in intrapsychological functioning), and referencing (use of apparatus to for speaking of objects). Thus, language and problem-solving tasks can serve as markers for developmental progress, though no end objective can be predicted from such markers.

Labouvie-Vief (1985) used these principles to contend that earlier findings that concluded older adults lacked logical competence may be simply interpreting the context of the problem-solving tasks in a different way than younger adults. Indeed, Labouvie-Vief argued that older adults who scored poorly on problem-solving when examining literal interpretation of the problem showed much higher sophistication and adaptation when

considering the processes of how they came to their conclusions.

Schemata

One similarity that exists in virtually all of the approaches but has not been addressed yet is the notion of schema. Titchener (1910) very early uses the concept to identify stimulus error in organisms. Gestaltists such as Koffka, Kohler and Wertheimer saw growth as the development of increasingly logical, complex and numerous schemata. Piaget uses the term in much the same way and also uses the term to identify certain knowledge structures within the organism. Likewise, information-processing theorists such as Newell and Simon saw schema as an important concept for the development of artificial intelligence programs. Vygotsky discusses explanatory principles that guide forces of development as critical to understanding cognitive growth. This, too, can be viewed as a schema, or pattern for structuring growth. The concept differs among perspectives in the rigidity of the schema and the source of the schema's creation. But in spite of these differences, all of the theorists seem to accept the general notion that there is some form of patterning that takes place within the human mind that facilitates cognitive growth.

Implications

Applying Cognitive Science Theory to Instructional Design in Multimedia

Obviously, there is much contradiction and confusion in the science of trying to make sense of how we make sense of the things around us. The individual that takes on the task of designing an instructional tool that will most effectively do the task of aiding student learning is faced with a difficult decision-making process. Clearly, there is no one correct solution to the multifaceted problems the instructional designer must face. However, this is not to say that no rationale is necessary in making important design decision. This section will attempt to make that decision-making process less intuitive and based more on the

principles of cognitive development that stem from the various theories previously described.

What should become apparent to the instructional designer is that the overall design of any project inevitably will stem from a philosophical viewpoint concerning cognitive development. However, this is not to say that combining elements from the various cognitive theories cannot be employed. On the contrary, once informed of the differing positions, designers could more effectively and with greater rationale attempt to cross boundaries that individual theoretical positions may be unable to accomplish. Consequently, the designer should begin with an established frame from which to view the overall project, but should also consider the audience that will be targeted for the instructional project and determine what other strategies may be useful.

Since incorporating all technological devices is not possible in the scope of this project, this section will focus on two areas that are more designer shaped than traditional classroom learning--computer-assisted instruction as a starting point leading to interactive-videodisc technology. However, many of the general principles forwarded can be incorporated into many, if not most instructional environments. The following section addresses how certain design features may appear in these contexts when built around the various cognitive theoretical stances.

Applying Shared Cognition Constructs to Instructional Design

One of the common themes that was suggested by all of the cognitive theories was the notion of the existence of schemata. These schemata, or organizational patterns, suggest that all curriculum must be placed into a form that resembles a type of patterning. However, this is not to say that the patterning must be linear. Though all the theories suggest patterns, they all also suggest that individual schemata are just that--individual. In other words, being able to design a patterning sequence that would match even several individuals would be an

impossible task. What this does suggest is that the instructional designer may wish to provide a framework for the learner to help develop their own adapted organizational pattern for the information.

One method of operationalizing this concept would be to offer a preview or advance organizer that identifies either desired objectives of the course or certain key concepts that the instructional designer expects the learner to achieve. Thus, the instructional designer must begin with a notion of what he or she expects the course to do for the individual. The instructional designer should not begin by saying that by the end of the course the learner should know *x* amount of data, which is frequently the goal; rather, they should assess how they desire the learner to cogitate over the material while involved in the learning process. By setting a certain quantifiable end point for the learner, the designer may in fact be limiting the end point attainable by the student. Or in an opposite direction, by placing quantifiable end points that are too high given a certain time frame, the designer may frustrate the learner out of the learning process altogether. Some courses certainly require prerequisite knowledge in order to accomplish the necessary work, but if instructional designers were to apply cognitive science principles in accommodating how people think and not just what to think, then the ends being sought might more readily be attained.

Applying organismic developmentalism

Organismic developmentalism suggests that all individuals go through stages that have certain identifiable characteristics. This has become an important consideration for instructional designers. Walshok (1989) points to needs assessment as an important ingredient to instructional design. Although most instructional designers view needs assessment as a pragmatic issue and not theoretical, needs assessment can be viewed as an extension of stage development and desired end states for learners. However, when placed

in the context of electronically mediated learning situations involving a potentially diverse learning group with respect to skill level, content familiarity, experience, etc., how is needs assessment operationalized? One application of this principle is to incorporate pretesting devices in the computer assisted instruction (CAI) or the interactive videodisc (IV) programs.

At start-up, new learners could be required to sign onto the system and in the process of signing on they could be evaluated by the computer in such areas as device familiarity, existing knowledge of content to be covered, problem-solving skills, or other domain specific tasks that are conceivably measurable. One element that might make this undesirable would be in the motivational aspect of the instructional design. If a participant begins with what may be construed a negative experience, the user of the technology may be less inclined to continue usage. Thus, the instructional designer may desire to incorporate the results blindly into the design--not reveal to the participant or to anyone else their performance or that they were indeed being evaluated by the system. This system would require that anonymity be incorporated into the initial evaluation stage and could be by-passed once a particular individual had successfully completed the evaluation tasks based on previous log-in passwords or codes.

Since organismic developmentalism presupposes that learning is the result of internal growth of the individual, the principle of self-directedness can be extended as another important construct that yields specific design considerations. Knowles (1984) and Schaie (1977/78) have incorporated this concept as a central component in their theories of adult education and has been forwarded by many in education (e.g. Merriam, 1988; Cross, 1975). Essentially, what would be necessary in a CAI curriculum design is the ability for the learner to explore material at their own discretion. Multiple pathways through information would be required for the individual to be able to pursue interest areas and to discover other relevant

interactions between the topic at hand and interrelated aspects of the topic.

Those learning theories labeled discovery learning or generative learning most probably could be classified as organismic developmental cognitive approaches and can be applied to multimedia in this manner. If relying on a text-only system, a program that facilitates the networking of information such as the HyperCard program for Macintosh computer systems would provide an ideal frame for such a structure. A concept could be linked to other terms, other environments, or other views on the related position. Given the advent of CD-ROM devices and the coming utility of CD-I, creating a database with enough information to genuinely explore has now become a reality. Though the task of the designer is complicated and possibly confounded by untold pathways for investigation, the designer can develop open loops in the system that allow information retrieval and storage for future application in both the CAI and IV environments.

Equilibration would suggest that in order for cognitive development to take place, then the environment (the CAI or IV, in this case) would necessitate offering an alternative reality or new experience that challenges the user of the system to assimilate or accommodate for the new or challenging information. Again, the need for being aware of the individual's situational state is necessary in order to adequately support a system designed around this premise. If a learner is presented with old information, according to Piaget and others, then the forwarding of cognitive development will not ensue at the rate possible if continually new, unusual, or contradictory information is offered. Thus, one possible approach is to set up questions in either CAI or IV environments that are in direct contradiction to what is known and the user of the mediated learning device is forced to support why their position is more valid than that being presented by the system.

Again, the instructional designer is faced with a motivational problem. How does the

person using the system not become frustrated when regularly confronting contradictory information? One method is to incorporate a mixed bag of scenarios, some being true and some being false. Along with this option, the designer might in some way provide reward or incentive for the process in order to encourage positive affect concerning the process of the learning experience. Rewards and incentives would not stem from an organismic developmental approach, rather, this kind of approach to learning would most closely fall into line with behaviorism.

Applying Behaviorism to Instructional Design

Salomon (1979) suggests that behaviorism does not lend itself well to application to instructional media. However, he also does make efforts to extend Bandura's social learning theory in order to make the cognitive theory fit into an instructional media system. Salomon adds a developmental dimensional to Bandura's scheme of reciprocal determinism. Salomon suggests that if an individual is involved in an interaction that involves modeling certain tasks, then in the process of the modeling the individual will experience a gradual addition of cognitive skills that will equip that individual with the ability to successfully carry out the task. Thus, a familiar approach to education--repetition, emerges as a possible applied design tool for many forms of mediated learning.

By exposing the individual learner to the same or related events repeatedly, then the learner is thought to gradually absorb some of the information and incorporate that information into long-term storage. Again, motivational factors come into play as a significant area for concern with this design approach. The designer must carefully consider how to present the same material in such a way as to not bore, offend, or otherwise alienate the user of the learning technology.

Behaviorism does give the instructional designer an approach that deals with the

affective domain to a limited extent. As was mentioned previously, providing a reward or incentive can be seen as a behaviorist design strategy. Incorporating affect can be extended as a reason for applying strategies of persuasion to the instructional design. By involving the participant emotionally into the subject matter, the learning experience could create a level of ownership for the learner. One example would be in studying a subject such as American History. By invoking appeals based on patriotism, challenging existing rights to free speech, or showing how the United States would be different if events had not happened as they did could involve an American audience to the degree that the learner would be more inclined to retain the information based on a behaviorist theory.

Information processing as applied to instructional design

As was stated in the introduction, this approach typifies the work currently being done in instructional design. Because of this situation, a detailed summary of all possible extensions of the principles to instructional design will not be attempted. However, significant concepts that are frequently occurring in instructional design will be briefly addressed.

Possibly the most frequently cited application of information processing to instructional design is chunking (e.g. West, Farmer, & Wolff, 1991). This is a term derived from the limits that are thought to be surrounding the storage facilities of the mind-brain. Since information processing suggest a finite capacity, particularly for sensory and working memory stores, chunking provides a way for the instructional designer to not overload the learner. Chunking is simply the dividing up of large amounts of information into more easily managed related units of information. Thus, the instructional designer must decide how large the information units should be, what will be the defining parameter for a chunk, and determine how to integrate the chunks into the overall schema for the instructional

design.

Chunking of information often is associated with another instructional design strategy--mnemonic devices. Mnemonics frequently are language-based learning aids that assist in the categorization of information. Acronyms where each letter of the word represents an important term or concept are common forms of mnemonics. Mnemonics can also be encoded using pictographs or icons. These pictures function as memory hooks where each representation has incorporated several notions that make up the image. Conceivably, an individual could conjure other sensory images for use in supplementing memory skills, but none were noted in use in instructional design. Thus, an instructional designer could build an entire program around several mnemonic devices arranged in such a way as to lead to some end objective. This process is closely related to another information-processing technique--imaging.

Imagery that is generated by the instructional designer in the form of mnemonic devices can be useful, but another possible application to instructional design is in allowing the learner to generate their own imagery. By providing stopping points or image notebooks into a learning program, the instructional designer can provide an opportunity to concretize the images that are generated by the student by allowing the learner to draw, write down, or otherwise explore forms that evoke the material being studied. Prompting questions or learning "roadside rest areas" may provide enough opportunity for the learner to comprehend the more involved concepts before continuing down the network. Providing possible cues in the form of a picture icon library or questions that prompt related thoughts could help as well.

Related to imagery is a cognitive strategy known as frames. Broken down into type one and type two categories, frames are essentially large images that provide a graphic

representation of how the concepts interrelate. Framing, thus, provides a more detailed picture than simple imagery or certain mnemonic devices. This type of strategy falls under the general umbrella of spatial learning. A frame can be designed around matrices that employ two- or three-dimensional levels of interaction. The notion of framing is closely linked to the concept of cognitive mapping. Framing, however, provides a map in form; whereas, cognitive mapping is a process that is developed by the individual to suit particular situations.

The vast number of strategies that can be developed from information processing is a possible advantage of the system. The system assumes that all individuals process information similarly regardless of the background or the situation. However, this lack of sensitivity to different situations is a distinct disadvantage of information processing. This disadvantage is a major factor for what has lead to contextualism.

Contextualism as the Applied Instructional Design Theory of the Future

In spite of the fact that information processing theory dominates the typical instructional design literature, a key figure in instructional design, Gavriel Salomon, and a key figure in the psychology of communication, James Wertsch, stand out as heralding a new era of applied media. Interestingly, both emerge from a very contextualistic perspective and base much of their work on the central contextualist, Lev Vygotsky. The failure of both organismic developmentalism and information processing to predict human performance across a wide range of environments has lead to the development and initial application of this approach.

Contextualism has begun to be more developed and studied as an applied science. Yet, the numbers of researchers looking at this approach does not compare to the previous

theories already addressed. Some of the possible applications will be discussed here.

An idea that was addressed as a possible application in information processing--imagery, has also been considered as a contextualist strategy to instructional design. Salomon, Globerson, and Guterman (1989) think of imagery as a method to reach what Vygotsky termed the zone of proximal development. This is a process of internalization where the student brings the information to him or herself and develops the information to generate stimulation. How this differs from information processing is that contextualism suggests that this approach encourages metacognition--thinking about one's own thinking. Metacognition, then, will more rapidly press the student to develop cognitive skills needed to match the tasks at hand. Questions such as what are you thinking at this moment?, how would you apply this concept to a different environment and why?, and by what process did you reach the conclusions you have made? would be examples of applying this notion to adult instructional design.

Another strategy suggested by Salomon (1988) and Salomon and Perkins (1987, 1989) is that of "high-road" and "low-road transfers." The low road equates into intuitive thinking that does not consider the future alternatives. The high road, by contrast, establishes a more in-depth rationale and promotes stimulation toward cognitive growth. These constructs are modes of thinking that can be operationalized into an instructional design by showing the learner the logic and thinking connections necessary. By revealing specific approaches to cognition, the instructional designer actually is attempting to shape the internalized cognitive style of the learner. Salomon suggests that one approach to this training is encouraging computer programming coursework for those individuals that lack some level of cognitive skill.

A technique first developed by Ausubel (1968), but seems to fit well into the

contextualist perspective is that of anchoring devices. Ausubel, and later Spiro and Jehng (1990) suggest selecting a micro event as the focus of a learning experience. With IV this can be a movie clip, or with a CAI this can be a single passage of text or a short animated scene. Regardless of what is chosen as the anchor, the instructional designer attempts to take the student into the anchor from as many possible angles and evoke many potential questions and responses. One way to approach this anchoring technique is to view a complex scene from biological, psychological, physiological, and sociocultural perspectives. Essentially asking who or what the actors are, why they are performing in such a manner, what interactions are taking place, and what outside factors shape the actors. This type of strategy could provide a means through which instructional designers could integrate curricula and provide a reason for the question: Why do I need to know this? Videodisc provides a superior medium for this approach since it has the capability to go to any segment of the anchored image and recall exactly what the student desires to see.

Since contextualists believe that the environments of the various learners inherently are active, an instructional program designed to teach a specific set of ideas could be built with a variety cultural perspectives in mind. By more finely attending to specific subcultures of America or of cultures stemming from other nationalities, then the disparity in learning achievement that has been recently noted could be equalized.

Spiro and Jehng (1990) term this approach to anchoring and cultural sensitivity as the cognitive flexibility theory. However, this approach seems more an application of contextualism than an entirely new theory. But regardless of the label, this approach offers the instructional designer a manner in which to explore a single anchoring device with thoroughness and sensitivity to a variety of peoples.

Finally, one approach that integrates a sophisticated form of videodisc technology that

may provide a means to dramatically alter the environment of the learner is in the use of virtual reality. By incorporating virtual reality goggles and headphones as opposed to the traditional monitor and speaker set-up, the instructional will soon have available the ability to take the learner to a host of places and to experience a number of activities without having to leave the learning center. The impression of being in another locale will, as the name implies, be virtually real. If indeed the environment is inherently active in the development of cognitive skills, then presenting learners with an alternate environment will ultimately lead to higher levels of cognitive development. Thus, the instructional designer will more carefully need to consider not only the design of the instructional program, but must consider the design of the presentation equipment itself before the development of a specified program.

Conclusion

Obviously, there is no single dimension of learners that predicate employing specific cognitive strategies in all circumstances. This paper has outlined in its contents just a few of the possible strategies to employ. However, what is clear is that cognitive science is going to be taking a more active role in instructional design.

The instructional designer must make decisions as to what approach and structure will most suit his or her targeted audience. Making these decisions based on intuitive sense as opposed to firm theoretical grounding will make it more difficult to forward instructional designs in the future.

Organismic developmentalism, behaviorism, information processing, and contextualism all offer viable applications to instructional design incorporating multimedia. However, one avenue that appears to hold the greatest promise for further research is within a frame that incorporates the individual, the environment, and the system acting one upon the other--

contextualism. Salomon (1988), Rebok (1987), Nix and Spiro (1990), and Wertsch, (1985) all point to this direction as the future for cognitive science .

Questions such as viewing how the environments shapes an individual schemata, does internalization develop when exposed to externalized cognitive strategies or is it simply a function of the individual, and can multimedia applications better adapt to varying cultures than traditional learning environments involving single culture instructors are all worthy of further study.

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