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Cognitive Conceptions of Learning

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ABSTRACT. Although cognitive psychology currently represents the mainstream of psychological and educational thinking, it is only recently that much concern has been shown for learning as such — that is, concern for the factors and/or variables that influence *changes* in human performance, knowledge structures, and/or conceptions. This article examines current thinking about learning within the framework of cognitive psychology and how a new, cognitive conception of learning can guide future research on both learning and instruction. Similarities and differences between behavioral and cognitive conceptions of learning are discussed, along with issues such as the active (rather than passive) nature of learning, the concern for understanding (i.e., comprehension), the role of prior knowledge, the cumulative nature of most forms of human learning, and the role played by cognitive analyses of performance. Several cognitive theories of learning are presented as examples of how cognitive psychology has influenced research on learning.

Psychologists and educators have long been interested in understanding how people learn, for the concept of learning is central to many different human endeavors. Teaching, child rearing, counseling, and a wide variety of training situations, to name just a few areas, are all concerned in one way or another with individuals learning new knowledge and/or behavior. There is, of course, a long history of empirical research on learning dating back to the classic research of Ebbinghaus (1913) first published in 1885. During the first half of the present century, research on learning flourished (nearly all of it within the behavioral tradition of psychology), and learning theory exerted a strong influence on research and practice in many different spheres of psychology and education.

This influence and interest in learning remained strong well into the 1960s. During the late 1960s and early 1970s, however, the *zeitgeist* of psychology began to change from a behavioristic to a cognitive orientation. Concern for the mind and the way it functions returned to scientific psychology. This cognitive orientation was clearly evident in research on topics such as meaningful verbal learning (Ausubel, 1962, 1963), discovery learning (e.g., Bruner, 1957, 1961), imagery (Paivio, 1969, 1971), "mathemagenic" behaviors (behaviors that give birth to learning) (Rothkopf, 1965, 1970), generative learning (Wittrock, 1974, 1978), and mnemonics (e.g., Bower, 1970).

Nevertheless, during the period from about 1960 to 1980, research on learning per se — that is, a concern for those factors that produce *changes* in an individual's behavior and/or knowledge — diminished drastically. For a variety of reasons (some of which will be discussed below), cognitive psychologists' interest in learning gave way to other concerns. Cognitive psychologists occasionally acknowledged the importance of learning, but little effort was devoted to furthering our understanding of how learning occurs. In appraising this situation, Voss (1978) concluded that "although the concept of learning may be found in cognitive psychology, it also must be conceded that the cognitive view of learning is vague, is abstract, and, most important, is lacking a substantive data base" (p. 13). Similar conclusions were voiced by other cognitive psychologists (e.g., J. R. Anderson, 1982; Greeno, 1980a; Langley & Simon, 1981).

Since about 1975, however, cognitive psychologists have shown a growing interest in learning, and a new era of research on learning may be at hand. Much, but certainly not all, of this more recent research represents an information-processing orientation and involves sophisticated computer models of learning. As one might expect, these cognitive conceptions of learning (both the earlier and the more recent ones) differ from traditional, behavioristic conceptions of learning in ways that enrich our understanding of how humans acquire new knowledge and new ways of doing things.

The purpose of this article is to examine current conceptions of learning, primarily from the vantage point of modern-day cognitive psychology. To provide an appropriate perspective, however, similarities and differences between traditional and cognitive conceptions of learning will be discussed. After first highlighting some characteristics of traditional conceptions of learning, ways in which cognitive psychology has influenced research on learning will be considered. Next, several cognitive theories of learning will be described. Finally, implications for future research on learning and for educational practices will be outlined.

Traditional Conceptions of Learning

During the 100 years since Ebbinghaus' pioneering research, nearly all research on learning has been conducted within a behavioral framework. Although the Gestalt psychologists of the 1910s to 1930s (perhaps the chief forerunners of modern-day cognitive psychology) occasionally discussed learning, they were more interested in perception than in learning, and they usually interpreted learning in terms of perceptual principles of organization. For a variety of reasons (see, e.g., Stevenson, 1983), traditional research on learning focused primarily on animal learning rather than human learning (although this research has not been totally void of cognitive influence — see, e.g., Kimble, 1984). As a result, most research on learning has involved relatively simple forms of learning. Even in the case of human learning, most traditional studies of learning have employed simple tasks that involve memorization more than comprehension. But before continuing, perhaps it would be useful to consider what we normally mean by the term learning.

The Concept of Learning

The concern for learning, of course, focuses on the way in which people acquire new knowledge and skills and the way in which existing knowledge and skills are modified. Nearly all conceptions of learning have involved — either explicitly or implicitly — three criteria for defining *learning* (see, e.g., Shuell & Lee, 1976): (a) a change in an individual's behavior or ability to do something, (b) a stipulation that this change must result from some sort of practice or experience, and (c) a stipulation that the change is an enduring one. The primary purpose of the latter two qualifications is to exclude certain types of behavioral changes that do not seem to represent what we mean by learning (maturation, temporary changes due to drugs, etc.).

Although there appears to be general agreement among behavioral and cognitive conceptions of learning with regard to the defining characteristics of the underlying phenomenon, there are also a number of important differences between the two orientations. The only formal definition of learning from a cognitive perspective that I have been able to find (Langley & Simon, 1981) fits the above criteria almost perfectly: "Learning is any process that modifies a system so as to improve, more or less irreversibly, its subsequent performance of the same task or of tasks drawn from the same population" (p. 367). The main difference appears to be the emphasis on the performance of a system rather than on the behavior of an individual. Cognitive conceptions of learning, however, focus on the acquisition of knowledge and knowledge structures rather than on behavior per se, on ". . . discrete change between states of knowledge rather than [on] change in probability of response" (Greeno, 1980a, p. 716). The significance of this difference is not as minor as it might appear, for if it is knowledge that one learns, ". . . then behavior must be the *result* of learning, rather than that which itself is learned" (Stevenson, 1983, p. 214).

There also tends to be general (although not complete) agreement among behavioral and cognitive conceptions of learning that both environmental factors and factors internal to the learner contribute to learning in an interactive manner (e.g., Brown, Bransford, Ferrara, & Campione, 1983). As one might expect, however, the different positions disagree on which side of this learner-environment equation is most important. For example, behavioral approaches focus on changing the environment in order to influence learning (e.g., by providing reinforcement when the appropriate response is made), whereas cognitive approaches focus more on changing the learner (e.g., by encouraging the person to use appropriate learning strategies). There are also considerable differences with regard to both what is learned (e.g., behavior vs. structured knowledge) and the factors that influence the learning process (e.g., reinforcement vs. strategies for obtaining feedback).

The Transition Begins

Although the seeds of modern-day cognitive psychology were present during the 1930s (e.g., Bartlett, 1932; Tolman, 1932), they did not grow to fruition, especially with regard to learning, for many years. During the 1960s, research on learning, especially verbal learning (the main body of research on human learning during this period), began to undergo a change that reflected views more consistent with cognitive interpretations of behavior. Investigators began to question, for example, whether simple conceptions of learning could adequately handle the more complex forms of learning encountered in real-life situations such as the classroom. The debate about whether classical conditioning and operant conditioning represent one or two different types of learning (see Kimble, 1961) was extended by Gagné's (1962, 1965) postulation of eight types of learning, including complex forms of learning such as concept learning and problem solving. People started to realize that even simple learning materials (e.g., nonsense syllables, isolated words) have meaning and that this meaningfulness can influence the learning process (e.g., Underwood & Schulz, 1960).

The realization that learners were not passive during learning (e.g., Bruner, 1957; Miller, Galanter, & Pribram, 1960) began to spread. For example, subjects often selected a stimulus (the "functional stimulus") that differed from the one intended by the experimenter (the "nominal stimulus") (Underwood, 1963), and when allowed (e.g., the free-recall paradigm), they organized the material being learned in meaningful ways, even in the absence of obvious bases of organization (Shuell, 1969; Tulving, 1968). Thus, a transition had begun from a strictly behavioristic orientation to one that involved more cognitive activities. But somewhere in the transition the concern for learning got set aside.

There are many reasons for the demise of interest in learning. Among the more obvious reasons are the following:

1. The appearance of experimental data that were difficult to reconcile with existing theories of learning (see Stevenson, 1983; White, 1970). Included among the many examples of this problem are age changes in the solution of reversal-nonreversal shift problems (Kendler & Kendler, 1962), the presence of organizational patterns in free recall (Shuell, 1969), and the transfer data that led to the notion of the functional stimulus (Underwood, 1963).

2. The feeling that one must understand the nature of the performance system before one can investigate learning (Newell & Simon, 1972). It is difficult to study transitions between knowledge states without first knowing something about the knowledge states between which the transition is being made, a problem directly analogous to the classical requirements for operational definitions and criterion specification.

3. The realization that the laws of learning depend on the context in which it occurs and the prior knowledge of the learner (for a good discussion of this point, see Siegler, 1983).

4. The ability of fresh ideas to capture the interest of investigators becoming bored with decades of traditional thinking about learning — that is, the *zeitgeist* of cognitive psychology.

In addition, the cognitive psychologists of the 1960s and 1970s became interested in identifying and describing the various stages and processes involved in human information processing. This focus led naturally to a concern for the nature of the memory system rather than learning — that is, how knowledge is represented in memory rather than how changes in knowledge take place. Different research questions were being asked; different paradigms were being employed; different assumptions were being made; and different theories were being developed.

The Influence of Cognitive Psychology

Cognitive psychology is concerned with various mental activities (such as perception, thinking, knowledge representation, and memory) related to human information processing and problem solving, and it presently represents the mainstream of thinking in both psychology and education. The emphasis is no longer strictly on behavior, but on the mental processes and knowledge structures that can be inferred from behavioral indices and that are responsible for various types of human behavior. Thus, with regard to learning, the search by learning psychologists of the 1950s and 1960s for atheoretical, functional relationships (Underwood, 1964) has shifted to a concern for the thought processes and mental activities that mediate the relationship between stimulus and response (see, e.g., Wittrock, 1986).

Nevertheless, cognitive psychology has influenced learning theory and research in several significant ways, including (a) the view of learning as an active, constructive process; (b) the presence of higher-level processes in learning; (c) the cumulative nature of learning and the corresponding role played by prior knowledge; (d) concern for the way knowledge is represented and organized in memory; and (e) concern for analyzing learning tasks and performance in terms of the cognitive processes that are involved.

Learning as an Active Process

Cognitive approaches to learning stress that learning is an active, constructive, and goal-oriented process that is dependent upon the mental activities of the learner. This view, of course, contrasts with the behavioral orientation that focuses on behavioral changes requiring a predominantly passive response from the learner to various environmental factors. Although operant conditioning requires the learner to make an overt response (so that it can be reinforced), the active nature of learning suggested by cognitive psychologists is very different. The cognitive orientation, for example, focuses on the mental activities of the learner that lead up to a response, and it explicitly acknowledges the following: (a) the role of metacognitive processes such as planning and setting goals and subgoals (e.g., Brown et al., 1983; Flavell, 1981); (b) the active selection of stimuli (e.g., the distinction between functional and nominal stimuli; Underwood, 1963); (c) the attempt by learners to organize the material they are learning, even when no obvious bases of organization are present in the materials being learned (e.g., Shuell, 1969; Tulving, 1968); (d) the generation or construction of appropriate responses (e.g., Wittrock, 1974); and the use of various learning strategies (e.g., Weinstein & Mayer, 1986).

The suggestion that memory (e.g., Bartlett, 1932; Cofer, 1973; Jenkins, 1974) and learning (e.g., Wittrock, 1974) both require the learner to actively construct new knowledge and strategies is appealing to many cognitive psychologists, but these views are plagued with a theoretical paradox (see, e.g., Bereiter, 1985). The problem arises when a learner acquires a new cognitive structure that is more advanced or complex than the structures that are presently possessed. The paradox involves the need to explain how the learner can acquire the new cognitive structure without already having an existing cognitive structure more advanced or complex than the one being acquired — a situation that is easier to explain in terms of innate mental structures than in terms of learning. Bereiter (1985) suggests 10 "resources" that permit one to avoid this "learning paradox," but few studies currently support their validity.

Higher-Level Processes in Learning

Most cognitive conceptions of learning acknowledge the hierarchical nature of the psychological processes responsible for learning. Miller, Galanter, and Pribram's (1960) book, *Plans and the Structure of Behavior*, proved very influential in popularizing the notion that behavior is hierarchically organized. Since the late 1970s, the higher-level (superordinate, executive) processes of learners have typically been referred to as metacognition (see, e.g., Brown, 1978; Brown et al., 1983; Flavell, 1979). Although such analyses raise the homunculus or "inner man" problem, such concerns need not be fatal. (For a discussion of this problem, see Brown et al., 1983.)

Generally, two types of metacognitive activities are involved in learning. The first involves regulation and orchestration of the various activities that must be carried out in order for learning to be successful (planning, predicting what information is likely to be encountered, guessing, monitoring the learning process, etc.) (e.g., Brown, 1978). Since learning is goal oriented, the learner must somehow organize his or her resources and activities in order to achieve the goal. The second is concerned with what one does and does not know about the material being learned and the processes involved in learning it. Flavell and Wellman (1977) suggest four general classes of metacognitive knowledge: (a) tasks — knowledge about the way in which the nature of the task influences performance on the task; (b) self — knowledge about one's own skills, strengths, and weaknesses; (c) strategies — knowledge regarding the differential value of alternative strategies for enhancing performance; and (d) interactions — knowledge of ways in which the preceding types of knowledge interact with one another to influence the outcome of some cognitive performance.

An example of the hierarchical nature of learning is Sternberg's (1984a, 1984b) componential theory of knowledge acquisition. Sternberg suggests that performance is regulated by nine metacomponents (executive processes) such as "recognition of just what the problem is that needs to be solved" (Sternberg, 1984b, p. 165). These metacomponents operate on lower-level performance components (processes used in the execution of a task, such as encoding and comparison) and three knowledge-acquisition components:

> 1. *Selective encoding* (sifting out relevant information from irrelevant information, in the stimulus environment, in order to select information for further processing).
> 2. *Selective combination* (combining selected information in such a way as to render it interpretable; that is, integrating it in some meaningful way).
> 3. *Selective comparison* (rendering newly encoded or combined information meaningful by perceiving its relations to old information previously stored). (Sternberg, 1984b, p. 168)

These knowledge-acquisition components operate on a variety of cues present in the material being learned, although cue utilization is affected by moderating variables such as number of occurrences, variability of contexts, location of cues, importance of the to-be-learned information, and density of the information to be learned (Sternberg, 1984a).

The Role of Prior Knowledge

Learning is cumulative in nature; nothing has meaning or is learned in isolation. Cognitive conceptions of learning place considerable importance on the role played by prior knowledge in the acquisition of new knowledge. Whereas traditional research on verbal learning was concerned with transfer and the effect of proactive inhibition on retention, concern for what the learner had already acquired focused on associations between individual stimuli and responses rather than on the acquisition of meaning from organized bodies of knowledge.

In the early 1970s, several studies (Bransford & Johnson, 1972; Dooling & Lachman, 1971) demonstrated that what the learner already knows and the extent to which this knowledge is activated at the time of learning has important implications for what will be acquired and for whether or not the material being studied will make any sense to the learner. Realizations such as these led to the development of schema theory (e.g., R. C. Anderson, 1984), which stresses that the organized, structured, and abstract bodies of information (known as schemata) that a learner brings to bear in learning new material determine how the task is interpreted and what the learner will understand and acquire from studying the task.

The traditional concept of transfer was concerned with the way prior learning influences later learning, and this influence was explained in terms of the similarity between stimuli and responses in the two situations. The newer cognitive concern for the role of prior knowledge in learning, however, recognizes that for meaningful forms of learning this process is more complex than the one suggested by earlier approaches to transfer. For example, Bransford and Franks (1976) suggest that the role of prior knowledge is to establish "boundary constraints" for identifying both the "sameness" and the "uniqueness" of novel information: "From the present perspective, growth and learning do not simply involve an expansion of some body of interconnected facts, concepts, etc. Learning involves a change in the form of one's knowledge so that it can set the stage for new discoveries" (p. 112). Likewise, within the context of cognitive development, Siegler (1983) and Siegler and Klahr (1982), among others, have emphasized the importance of prior knowledge (especially the rules used to perform various tasks) in determining when children are ready to learn new material.

Another change that has occurred recently is an emphasis on domain-specific knowledge and learning skills (e.g., Glaser, 1984). Although this change in thinking cannot be attributed directly to the rise of cognitive psychology, it has had a substantial influence on cognitive conceptions of learning. Traditional research on learning sought general laws applicable to all individuals and all subject-matter areas. However, recent research on individuals with differing levels of expertise in a particular subject, such as physics (e.g., Chi, Glaser, & Rees, 1982), has shown convincingly that experts and novices solve problems in fundamentally different ways. Although controversy remains over the relative importance of domain-specific knowledge and general, domain-independent learning strategies (e.g., Block, 1985; Glaser, 1984; Sternberg, 1985), it is generally recognized (e.g., Glaser, 1985; Keil, 1984) that both are important in most learning situations. Consequently, there is an important relationship between the emphasis on domain-specific knowledge and the concern for prior knowledge that is evident in research on cognitive learning.

The Question of What is Learned

One major difference between behavioral and cognitive conceptions of learning concerns the nature of what an individual learns. Behavioral approaches typically suggest either that the learner acquires associations or "bonds" between a stimulus and a response (e.g., Thorndike, 1913) or that the issue of what an individual might acquire internally (i.e., "theories" of learning) is totally irrelevant for understanding the factors responsible for learning (i.e., changes in behavior) (Skinner, 1950).

Cognitive psychologists, on the other hand, are primarily concerned with meaning rather than with behavior per se — that is, a concern for the manner in which an individual extracts meaning from some experience. The emphasis is on understanding, not merely on learning how to perform a task, and on the acquisition of knowledge rather than on the acquisition of behavior. If knowledge is what an individual learns, then behavior is the *result* of learning rather than what an individual acquires (Stevenson, 1983). Generally, this knowledge is best represented by complex knowledge structures rather than by simple associations.[1]

These knowledge structures are usually conceptualized as networks of information specifying the relationship among various facts and actions (e.g., J.R. Anderson, 1980; Norman et al., 1975). There are, however, other ways of conceptualizing what an individual acquires in cognitive learning. For example, both Scandura (1970, 1977) and Siegler (1983) have suggested that rules are useful units for characterizing what people learn. Actually, it seems likely that humans have several different ways and/or modes for representing knowledge. For example, a distinction is frequently made in cognitive psychology between propositional (or declarative) and procedural knowledge, and it appears likely that there are several additional forms of knowledge representation (e.g., Gagné & White, 1978; Shuell, 1985) and several different memory systems (Tulving, 1985).

Cognitive Process Analysis

One important consequence of the cognitive influence on learning has been an interest in analyzing performance and cognitive abilities in terms of the cognitive processes involved in performing a cognitive task, including performance on tests of mental ability such as intelligence (e.g., Carroll, 1976; Snow & Lohman, 1984; Sternberg, 1979), inductive reasoning (e.g., Pellegrino & Glaser, 1982), and deductive reasoning (e.g., Johnson-Laird, 1985). For example, Sternberg (1977) proposed that analogical reasoning — which some (e.g., Rumelhart & Norman, 1981) have suggested is the basis of cognitive learning — involves six cognitive processes: (a) encoding the various terms that make up the analogy, (b) inferring the relationship between the first two terms of the analogy, (c) mapping or discovering a higher-order rule that relates the first and third terms of the analogy, (d) applying the results of the inferring and mapping components to the third term in order to generate an appropriate fourth term, (e) an optional justification process in which one of the answers provided is selected as being the closest to the "ideal" answer produced by the application process, and (f) a response process whereby the solution is translated into a response.

This type of cognitive process analysis also has been applied to various types of instructional tasks such as the learning of geometry (e.g., Greeno, 1978, 1980b), physics (e.g., Champagne, Klopfer, & Gunstone, 1982; Heller & Reif, 1984), reading (e.g., Omanson, Beck, Voss, & McKeown, 1984), and addition and subtraction (e.g., Carpenter, Moser, & Romberg, 1982). Such analyses can help us to better understand both the cognitive processes involved in learning and the instructional techniques most likely to facilitate that learning.

[1] Most discussions of knowledge structures by cognitive psychologists go beyond the associative networks and habit-family hierarchies sometimes discussed by associationists.

Cognitive Theories of Learning

Most cognitive conceptions of learning reflect an overriding concern for the more complex forms of learning, that is, the types of learning frequently characterized as "meaningful" or where one "learns for understanding." For the most part, cognitive psychologists have been interested in the latter approach. As Norman (1978) put it:

> I do not care about simple learning. . . . that only takes 30 minutes. I want to understand real learning, the kind we all do during the course of our lives. . . . I want to understand the learning of complex topics. . . . [those] with such a rich set of conceptual structures that it requires learning periods measured in weeks or even years. (p. 39)

One problem with meaningful learning is that it is difficult to define. Although an operational definition is not readily available, it is possible to provide examples of the differences that concern many investigators. It makes little sense to most people, for example, to say that one "understands" his or her phone number; we "can learn, know, or remember a phone number, but not understand one" (Markman, 1981, p. 63). Only information that is structured or organized can be thought of as being meaningful and can serve as an object of understanding (Bransford & McCarrell, 1974; Moravcsik, 1979). Although some investigators would apparently limit cognitive learning to the acquisition of information that is structured or organized, higher-order thought processes are involved in many forms of simpler learning as well (e.g., when elaboration occurs or when mnemonics are used — see Pressley & Levin, 1983a, 1983b). It seems reasonable to suggest that all of these different types of situations fall within the domain of cognitive learning.

Various attempts have been made over the years to articulate the role of learning from a cognitive or human information-processing perspective (for a detailed discussion of these approaches, see Bower and Hilgard, 1981). The following discussion will focus on those theories that have most influenced current thinking and research on cognitive learning.

Early Conceptions

During the late 1950s and early 1960s, several writers began to formulate cognitive theories of learning. For example, Bruner (1957, 1961) talked about learning in terms of "discovery" and "going beyond the information given." According to Bruner (1957), learning occurs when an "organism . . . code[s] something in a generic manner so as to maximize the transferability of the learning to new situations" (p. 51). He goes on to identify four general sets of conditions under which such learning will occur: (a) the "set to learn" or "attitude toward learning", (b) an appropriate need state (in which an "optimal" level of motivation is discussed), (c) prior mastery of the original learning (and its importance for generic coding), and (d) diversity of training.

The first systematic model of cognitive learning, however, was Ausubel's (1962, 1963) subsumption theory of meaningful verbal learning. Ausubel makes clear that the theory is concerned only with "meaningful" (as opposed to "rote"), "reception" (as opposed to "discovery") learning. According to this theory, new, potentially logical information is subsumed (incorporated) into the learner's existing cognitive structure. The availability of an existing cognitive structure — hierarchically organized with progressive differentiation within a given field of knowledge from more inclusive concepts to less inclusive subconcepts — is seen as the major factor affecting meaningful learning, and the use of "advance organizers" (models or other types of representation that provide a structured overview of the material to be learned) can help ensure that such availability exists. Another major factor is the extent to which the new material is discriminable from the existing cognitive structure that subsumes it. This discriminability can be facilitated by repetition and/or by explicitly pointing out the similarities and differences between the new materials and their presumed subsumers in cognitive structure. Finally, the retention of meaningful material was thought to be influenced by repetition, the length of time that relevant subsuming concepts had been part of the learner's cognitive structure, the use of appropriate exemplars, and multi-contextual exposure.

Another early theory of cognitive learning was Wittrock's (1974) model of generative learning. According to this model (Wittrock, 1974, 1978), people learn meaningful material by generating or constructing relationships among new information and knowledge already stored in long-term memory. These verbal and imaginal elaborations occur as the learner seeks to discover the underlying rule or relationship "by drawing inferences [about the rule], applying it, testing it, and relating it to other rules and to experience" (Wittrock, 1978, p. 26). It was recognized that individuals might proceed differently and that different instructional adjuncts could elicit the appropriate cognitive processes. It appears that the primary mechanisms of learning, according to the generative model, consist of the learner making inferences about potential relationships and then actively seeking feedback on the adequacy of these relationships.

Bransford and Franks (1976) suggested that understanding or comprehension involves the acquisition of novel information that is difficult, if not impossible, for the traditional, "memory metaphor" model of learning to explain. They suggest that learning that involves understanding (i.e., comprehension) occurs via a process of decontextualization. That is, knowledge is initially acquired in a specific context; in order for understanding to occur, this knowledge must become more abstract so that it can be related to a variety of different situations. A mechanism for this decontextualization process is not suggested, but Bransford and Franks suggest that concepts and knowledge become abstract by virtue of being used to clarify a number of situations, and thus stress the importance of the learner encountering relevant examples.

Most of the more recent work on cognitive learning has occurred within the area of artificial intelligence (AI), where the goal has been to develop computer programs that can learn. A concern for simulating learning was present in some of the early work on AI—for example, the EPAM model (Feigenbaum, 1959; Simon & Fiegenbaum, 1964). Since about 1975, this interest has intensified, especially with regard to J. R. Anderson's (1982, 1983) ACT theory. The programs of interest here are those intended to serve as models or theories of human cognitive learning. In general, attempts to define cognitive learning have emphasized a system of processes, relationships among concepts and/or facts, and the restructuring of schemata. The similarities and differences between behavioral and cognitive conceptions of learning can be illustrated by considering several prominent theories of cognitive learning and the mechanisms considered to be responsible in the psychological changes we refer to as learning.

Rumelhart and Norman

The first comprehensive theory of cognitive learning was Rumelhart and Norman's (1978) attempt to account for the process of learning within a schema-based theory of long-term memory, although they emphasized that "learning is not a unitary process: No single mental activity corresponding to learning exists. . . . and no single theoretical description will account for the multitude of ways by which learning might occur" (p. 50).[2] Rumelhart and Norman suggest three qualitatively different kinds of learning: (a) *accretion*, or the encoding of new information in terms of existing schemata; (b) *restructuring or schema creation,* or the process whereby new schemata are created; and (c) *tuning or schema evolution*, or the slow modification and refinement of a schema as a result of using it in different situations.

Most models of memory involve learning by accretion. New information is interpreted in terms of preexisting schemata, and this process occurs most readily when the material being learned is consistent with schemata already available in memory. The new information is added to knowledge already in memory without any changes being made in the way that knowledge is organized. Accretion involves the acquisition of factual information that some people might refer to as memorization. Resnick (1984) refers to this type of learning as schema instantiation and suggests that it is similar to the Piagetian concept of assimilation. Norman (1978) suggests that ". . . accretion learning requires study, probably with the use of mnemonic aids (and deep levels of processing). It can be tested by conventional recall and recognition techniques" (p. 40). Interference from related topics tends to be high and transfer to related topics tends to be low.

Tuning and restructuring are similar to the Piagetian concept of accommodation (Resnick, 1984). Restructuring may occur without any formal addition of new knowledge — that is, the learner may already have all of the necessary information and the only thing that occurs is a reorganization of existing knowledge. Rumelhart and Norman (1978) suggest two basic ways for restructuring to occur: (a) *schema induction*, which is a form of learning by contiguity in which certain spatial or temporal co-occurrence of schemata results in the formation of a new schema, and (b) *patterned generation*, in which a new schema is patterned (copied with modifications) on an old schema. Restructuring occurs as a result of encountering examples, analogies, and metaphors, as well as through tutorial interactions such as Socratic dialogue. Tests of restructuring should include conceptual tests and questions that require inference or problem solving (Norman, 1978). Generally, learning that involves the creation of new schemata occurs as the result of analogical processes — that is, we learn new schemata by relating new information to old schemata in analogical ways (Rumelhart & Norman, 1981).

Tuning involves the slow and gradual refinement of existing schemata, a process

[2] The suggestion that there is more than one type of learning is not unique to current concerns for cognitive learning. For example, Kimble (1961) discussed differences between classical and operant conditioning, and Gagné (1965) postulated eight different types of learning ranging from classical conditioning to problem solving.

that lasts a lifetime. Norman (1978) suggests that tuning is "... best accomplished by practice at the task or in using the concepts of the topic matter. Tests of tuning should be measures of speed and smoothness, [including] performance under stress or pressure" (p. 42). With tuning there is low interference from related topics, and transfer to related topics is high with regard to general knowledge and very low with regard to specific (tuned) knowledge.

John Anderson's ACT

Most cognitive psychologists distinguish between declarative and procedural knowledge. *Declarative knowledge* is our knowledge about things and is usually thought to be represented in memory as an interrelated network of facts (e.g., $2 + 3 = 5$, $5 \times 4 = 20$) that exist as propositions. *Procedural knowledge* is our knowledge of how to perform various skills (e.g., produce the correct sum when given an addition problem, solve a word problem). John Anderson (1982, 1983) has developed a computer program (i.e., a theory) called ACT (or ACT*, as the current version is called) that is capable of learning procedural knowledge such as solving geometry proofs and other types of problems. In contrast to Rumelhart and Norman's (1978) belief that there are many forms of learning, ACT is based on the presumption that a single set of learning processes is "... involved in the full range of skill acquisition, from language acquisition to problem solving to schema abstraction" (Anderson, 1983, p. 255). Since ACT is the most explicit and comprehensive of current cognitive theories of learning, it will be described in some detail.

The distinction between declarative and procedural knowledge is a fundamental part of the ACT theory. Declarative knowledge is represented in ACT as a *network of propositions* (i.e., statements of relationships among concepts, events, etc.), and procedural knowledge is represented as a *system of productions* (i.e., statements of the circumstances under which a certain action should be carried out and the details of what should be done when that action is appropriate). The theory is concerned with the acquisition of both declarative and procedural knowledge, as well as the transition between the two, although the emphasis is more on the latter than the former.

According to ACT, knowledge in a new domain always begins as declarative knowledge; procedural knowledge is learned by making inferences from facts available in the declarative knowledge system. Anderson (1982, 1983) suggests that three stages are involved in learning procedural knowledge: the declarative stage, the knowledge compilation stage, and the procedural stage. These stages are similar to the three phases of skill learning suggested by Fitts (1964). The ACT theory is basically organized for problem solving in the belief that problem solving is the basic mode of cognition (Anderson, 1982; Newell, 1980). Consequently, the ACT system is organized in a hierarchical, goal-structured manner, with both performance and the various learning mechanisms operating under the control of some goal or subgoal.

When new information is encountered, it is coded probabilistically into a network of existing propositions as declarative knowledge. The activation of various propositions in this network is determined by the strength of nodes — that is, points in the knowledge structure representing specific concepts, relationships among concepts (propositions), or images — which varies directly with practice and inversely with the passage of time. This declarative knowledge has little, if any, direct control on behavior. Rather, the impact of declarative knowledge on behavior, according to Anderson (1982), is

> filtered through an interpretive system that is well oiled in achieving the goals of the system. . . . New information should enter in declarative form because one can encode information declaratively without committing control to it and because one can be circumspect about the behavioral implications of declarative knowledge. (pp. 380–381)

During the declarative stage, general problem-solving procedures are used to interpret new information in a way that directs the learner's behavior toward dealing with the task at hand. At some point this declarative knowledge is compiled into higher-order procedures (productions) that apply the knowledge and increase efficiency in dealing with the learning task (e.g., problem). Finally, ACT uses an adaptive production system that engages in the type of learning referred to in the preceding section (on Rumelhart and Norman) as tuning, a process that refines the procedure. Three learning mechanisms are used as the basis of this tuning: (a) *generalization*, a process by which production rules become broader in their range of applicability; (b) *discrimination*, a process by which production rules become narrower in their range of applicability; and (c) *strengthening*, a process by which better rules are strengthened and poorer rules are weakened.

An example of how the ACT theory would explain the way a child learns to do addition problems would begin with statements (perhaps spoken by the teacher or read in a textbook) of certain facts such as: "In addition problems, one first adds the numbers in the rightmost column;" "Next, you add the numbers in the second column"[3] and so forth. With some practice (and perhaps examples by the teacher), these statements of fact are transformed into the ability to actually do what these statements say need to be done. (While many educators are aware that knowing about something does not necessarily mean that the student has acquired the procedures for translating that knowledge into practice, this distinction is made explicitly by cognitive psychology.) The ability to carry out the actions specified might be represented as productions (P) such as the following:[4]

P1. IF the goal is to do an addition problem,
THEN add the numbers in the rightmost column.

P2. IF the goal is to do an addition problem and the rightmost column has already been added,
THEN add the numbers in the second column.

With additional experience, these (along with other productions) might be compiled into the following, higher-order productions taken from J. Anderson (1982, p. 371):

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[3] The process of carrying will be ignored for the sake of simplicity.

[4] While individual productions may appear to some readers as being very similar to stimulus-response associations in which a particular response is under the control of a discriminating stimulus, production systems are different from S-R associations in the way individual productions are interrelated in an organized system under the control of various goals and subgoals. Note also how control of the system can be shifted from a goal to a subgoal, as in production P3 below.

P3. IF the goal is to do an addition problem,
THEN the subgoal is to iterate through the columns of the problem.

P4. IF the goal is to iterate through the columns of an addition problem and the rightmost column has not been processed,
THEN the subgoal is to iterate through the rows of the rightmost column and set the running total to zero.

These and other productions would then be compiled into yet other, more general productions that would enable the student to solve addition problems smoothly and efficiently. As other tasks are encountered, however, generalization may occur with the result that various production rules will become broader in their range of applicability. Generalization in ACT is similar to the traditional concept of generalization, except that in ACT generalization involves the learner (i.e., the program) searching for appropriate similarities among production rules and then creating a new production rule that combines those features that the two rules have in common. The search for rules is, of course, the feature that distinguishes this cognitive version of generalization from more traditional behavioristic ones. For example, in learning to solve addition problems, the student acquired production P3 above. Later, in learning to solve subtraction problems, the following production may be acquired:

P5. IF the goal is to do a subtraction problem,
THEN the subgoal is to iterate through the columns of the problem.

The similarity between productions P3 and P5 are noticed, and the following generalization is formed:

P6. IF the goal is to do an LV problem,
THEN the subgoal is to iterate through the columns of the problem.

LV is a "local variable" defined by the specific instances in which the production might apply. The new, more general production would not replace the two original ones; they would continue to apply in special circumstances. Transfer is facilitated, according to ACT, if the same components are taught in two different procedures so that the commonality is more likely to be noticed and generalization can occur. Thus, the transfer involved in learning to drive a new car will be greater if the individual has previously driven several different cars rather than only a single car, a position that is consistent with the results of a number of transfer studies (see e.g., Shuell & Lee, 1976, pp. 71–72) and more recent work on cognitive learning (e.g., Sternberg, 1984a).

There are, of course, many situations in which the range of applicability of a production needs to be limited — that is, discrimination needs to occur if the learner is to produce appropriate behavior. For example, in learning to solve addition problems, the student may have acquired the following production:

P7. IF the goal is to iterate through the rows of a column and the top row has not been processed,
THEN the subgoal is to add the digit of the top row into the running total.

Through the use of this production in a variety of different types of addition problems, generalization may have occurred. In fact, when first encountering subtraction problems, the learner may attempt to employ this production, which has worked in the past. Obviously, if the student is to be successful in solving subtraction problems, he or she must learn to discriminate between production P7 and a similar production in which the action specified involves subtracting (rather than adding) the digit from the running total.

Discrimination in ACT depends on the learner experiencing both correct and incorrect application of the production, a requirement that is consistent with the well documented need for the learner to encounter both positive and negative exemplars in concept learning (see, e.g., Tennyson & Park, 1980). Two types of discrimination are involved in ACT: *action discrimination* involves learning a new action and can occur only when feedback is obtained about what action is correct in the situation being considered. *Condition discrimination* involves restricting the conditions under which the old action was carried out, although the new, more restrictive productions coexist with the original production rather than replacing it.

Generalization and discrimination are viewed as the inductive components of the learning system embodied in ACT. Due to the nature of induction, generalization and discrimination will err and produce incorrect and/or inappropriate productions — for example, overgeneralizations and useless discriminations. A mechanism that strengthens successful productions will help to ensure that appropriate behavior will occur. While the strengthening mechanism in ACT is fairly complex, it functions basically by modifying the probability attached to a given production, depending on the positive and negative feedback it receives.

Implications for Future Research

A new wave of research on learning is beginning within the various cognitive sciences. Although much of this research holds promise for new and more powerful theories of human learning, considerable work remains to be done before a truly viable and comprehensive theory (or theories) of learning (i.e., capable of accounting for both simpler and more complex forms of learning) is available. As might be expected, given its relative newness, much of this research has focused on theoretical discussions of its nature and empirical demonstrations that certain types of processes and factors have been overlooked in traditional research on human learning — e.g., learners construct appropriate responses rather than merely react to environmental stimuli (see Wittrock, 1974) and encoding plays a crucial role in learning; see Siegler, 1983 and Sternberg, 1984a. A number of problems should be addressed by future research, and some of the challenges will be discussed in terms of: (a) variables that affect the learning process; (b) the relationship between knowledge and learning, including the role of prior knowledge and domain-specific versus domain-independent (general) aspects of learning; and (c) phases of learning.

Variables Affecting Learning

Little is known about the specific variables (e.g., environmental events) that influence the learning process. Future research should develop more precise, operational definitions of variables that can influence cognitive learning (e.g., those that a teacher or counselor might use in trying to facilitate the learning of a student or client) so that they can be systematically investigated. Current theories of cognitive learning have identified various functions that must be performed if learning is to occur. For example, Sternberg (1984a) suggests that many, if not all, cognitive theories of learning incorporate three functions that must be performed if learning is to occur: (a) the collection of new information (encoding), (b) the combination of disparate pieces of new information, and (c) the relating of new to old information. It seems to me that several other functions, such as evaluation, are also involved.

Little research has been done on variables that affect these factors within a complex learning situation (e.g., the specific variables that determine what does and what does not get encoded), although Sternberg (1984a) identifies and discusses five variables that appear to affect the learning of verbal concepts: (a) the number of occurrences of the new item of knowledge, (b) the variability of contexts in which multiple occurrences of the new item of knowledge occur, (c) location of cues relative to the to-be-learned item of knowledge, (d) importance of the to-be-learned item of knowledge, and (e) density of items of knowledge to be learned. It is interesting to note how similar most of these variables are to those variables responsible for more traditional types of learning (e.g., practice, contiguity, and reinforcement). (For a discussion of how these variables provide the basic conditions for learning to occur, see Shuell and Lee, 1976.)

In fact, it should be evident from the preceding sections that many of the current theories use traditional concepts from the psychology of learning to explain cognitive learning — for example, generalization. It has been suggested that new schemata are learned by establishing analogies between old and new schemata (Rumelhart & Norman, 1981). If such is the case, it seems likely that the process is one of generalization and transfer. But generalizations based on analogies may be rather different from traditional conceptions of generalization, since analogies involve structured relationships whereas traditional conceptions typically involve unidimensional stimuli and responses.

Tversky (1977) has proposed a contrast model of similarity in which perceived similarity is determined by the individual matching features (both common and distinctive) between two objects or families of objects (e.g., an analogy). The extent to which psychological processes related to generalization are the same in the two situations (traditional vs. cognitive learning) is an empirical question that remains to be investigated. For instance, if there are generalization gradients for analogies similar to those that exist for simpler forms of learning (and this assumption is not unreasonable), then what are the relevant dimensions in analogies along which generalization can occur and the structures to which they apply?

A variety of other variables such as elaboration and advance organizers that have been investigated within the traditional framework of research on learning clearly involve mental activities and make assumptions similar to those discussed above for cognitive learning. In addition, Norman (1978) has suggested various ways in which interference and transfer (two very traditional factors in research on human learning) might be involved in various types of cognitive learning. Although a detailed discussion of the possible integration of these variables and phenomena with the types of concerns associated with cognitive learning is beyond the scope of the present article, a simple example may prove useful.

Contiguity (the proximity of two events) is well established as one of the fundamental variables affecting traditional types of learning (e.g., Shuell & Lee, 1976). In these simpler forms of learning, contiguity is nearly always defined in terms of time intervals (e.g., the time between the conditioned stimulus and unconditioned stimulus in classical conditioning, the time between response and reinforcement in operant conditioning), but other forms of contiguity (e.g., spatial, semantic) appear just as reasonable. Thus, in learning more complex material, contiguity between disparate pieces of information may determine the likelihood that the individual will induce a schema. In Sternberg's (1984a) list of five variables affecting the acquisition of concepts from text, one (location of cues) is a clear example of contiguity, and another (density of items) could involve contiguity, (e.g., the point at which cognitive overload occurs). In some cases, the learner may actively try to establish contiguity through the use of various learning strategies. Although contiguity may seem like an esoteric variable to some educators, it is a variable over which teachers and instructional designers (e.g., textbook authors) have considerable control; if more were known about the way contiguity affects meaningful learning, perhaps they could use it more effectively. In any case, a combination of concerns from traditional learning psychology and modern-day cognitive psychology should serve as a focal point of future research on cognitive learning.

Knowledge and Learning

Traditional conceptions and theories of learning are, for the most part, content free — that is, learning occurs in basically the same way, or follows the same principles, in all situations. Gradually, however, it has become increasingly clear that the amount of knowledge that one possesses has a substantial impact on the learning process (e.g., Chi, Glaser, & Rees, 1982). For example, adults normally are able to remember more (e.g., have considerably longer digit spans) than children, yet Chi (1978) found that 10-year-old chess experts remembered more about the placement of chess pieces on a board than adults who were only novice chess players (the traditional finding of adult superiority was obtained when the same subjects were asked to remember digits). In addition, individuals who know a great deal about something (experts) encode new material related to that knowledge in a different way than individuals who know little about the topic (novices) (see, e.g., Chi et al., 1982; Siegler, 1983). While these expert/novice differences demonstrate that cognitive learning involves qualitative and not merely quantitative changes, we need to know more than the nature of the differences; we need to know how the transition between novice and expert takes place, especially if education is to facilitate the process.

There is also evidence that learning is much more domain specific than earlier learning theorists believed (for a good discussion of this point, see Glaser, 1984). For example, Chase and Ericsson (1981) report on an average college student (SF) who over a period of 25 months of practice steadily increased his average digit span from seven to over 80 digits. This feat was accomplished by encoding the digits into running times (SF was an avid and proficient long-distance runner) and developing an elaborate, hierarchical retrieval structure. But the skills SF learned in acquiring the largest memory span ever reported in the literature are domain specific; SF's memory span is normal (about seven symbols) when recalling other types of stimuli such as random consonants. Apparently SF lacked the knowledge base relevant to consonants, for example, that would be necessary to demonstrate his proficiency with other types of stimuli.

Yet it seems unlikely that all learning is domain specific. If it were, then it would be difficult to explain how individuals deal with novel situations or learn material that is totally new to them. Obviously, learning involves both domain-specific and domain-independent processes. One challenge for future research to address is how these two aspects of learning interrelate with one another and with the skill and/or knowledge that is being acquired.

Another issue that is likely to be addressed by future research is the relationship between various types of knowledge. As already noted, cognitive psychologists frequently distinguish between declarative and procedural knowledge, and other types of knowledge have also been suggested (e.g., Gagné & White, 1978). But is one type more basic than other types? For example, Rumelhart and Norman (1981) propose that "... all knowledge is properly considered as *knowledge how* but... the system can sometimes interrogate this *knowledge how* to produce *knowledge that*" (p. 343). This emphasis on "learning by doing" (Anzai & Simon, 1979) — "... expertise comes about through the use of knowledge and not by analysis of knowledge" (Neves & Anderson, 1981, p. 83) — is reminiscent of themes heard in education, although the emphasis is somewhat different. In any case, these issues have important implications for educational practices, since different types of knowledge have different instructional requirements.

Phases of Learning

The notion that learning progresses in what might be thought of as phases or stages is not a new idea. Some 30 years ago, Fleishman and Hempel (1954, 1955) provided evidence that psychomotor learning proceeds in this manner with performance in the various stages drawing upon different abilities. Other researchers provided evidence for stages in both paired-associate (e.g., McGuire, 1961; Underwood, Runquist, & Schulz, 1959) and free-recall learning (Labouvie, Frohring, Baltes, & Goulet, 1973). In addition Brainerd (1985) and Brainerd, Howe, and Desrochers (1982) developed a sophisticated mathematical model of learning. Nearly all of this research, however, deals with relatively simple forms of learning. Very little empirical evidence is available on the phases that learners might go through in learning more complex, meaningful material.

In recent years, several cognitive theorists have suggested that stages are involved in cognitive learning. For example, Bransford and Franks (1976) have argued that learning that involves understanding moves from concrete to abstract representations, and J. R. Anderson's (1982) ACT theory postulates that learning proceeds from declarative knowledge to procedural knowledge. Other types of stages or phases of learning are possible, and it is reasonable to expect that different variables may be involved during the various phases.

For example, in school we typically expect students to acquire complex bodies of knowledge with some degree of understanding. When the individual begins this undertaking, he or she normally begins by acquiring a number of relatively disparate pieces of information (e.g., the "basic facts" stressed in most classrooms). During this early phase of learning, pictorial and verbal mnemonics (or various other learning strategies) may facilitate learning by providing the conceptual glue necessary to hold these disparate pieces in memory, and variables such as repetition may play a relatively important role. As learning progresses, however, and the individual begins to fit some of the pieces together, mnemonics may play a less important (or different) role and other types of factors (organizational strategies?) may play an increasingly important role. Still later, as performance becomes well established, mnemonics may have little or no effect on learning since the underlying knowledge structure now holds the information together in some meaningful, integrated whole — to use an extremely elementary example, C - A - T has become CAT.

Thus, given variables may facilitate acquisition during one phase of learning and have little, if any, effect during other phases. Although retention is not really a phase of learning in the sense being discussed here, perhaps the relationship is similar enough to provide a useful analogy. Elaboration clearly has a facilitative effect on learning, but it has been found not to affect retention independent of learning (Olton, 1969); likewise, immediate feedback normally facilitates learning, but delayed feedback appears to facilitate retention (Surber & Anderson, 1975).[5] The more important forms of human learning that interest most cognitive scientists and educators involve what is fundamentally a long-term process involving weeks, months, and even years. The phases that we go through as we engage in long-term learning are unknown at present, but they undoubtedly exist and deserve our attention.

Implications for Education

Changes in the way we think about learning and what we know about the way learning occurs have important implications for those situations in which we want to facilitate changes in what people know and/or do. In education, for example, corresponding changes are occurring in the way we think about teaching. Since learning is an active process, the teacher's task necessarily involves more than the mere dissemination of information. Rather, if students are to learn desired outcomes in a reasonably effective manner, then the teacher's fundamental task is to get students to engage in learning activities that are likely to result in their achieving these outcomes, taking into account factors such as prior knowledge, the context in which the material is presented, and the realization that students' interpretation and understanding of new information depend on the availability of appropriate schemata. Without taking away from the important role played by the teacher, it is helpful to remember that what the student does is actually more important in determining what is learned than what the teacher does.

Although many educators have long advocated that teachers actively engage their students in the learning process, there has not been a great deal of scientific knowledge to support these contentions. "Open education" and "discovery learning" are just two examples of educational practices that failed to produce encouraging results due, at least in part, to the lack of a viable theory of cognitive learning. Many other educators, of course, have advocated "back to the basics" and other approaches stressing more behavioral forms of learning variables. With the advent of cognitive theories of learning and knowledge of how specific learning processes in the student are engaged by specific instructional variables, we may have the beginning of a viable body of scientific knowledge on how best to capitalize on the active nature of learning. Some of the cognitive research on learning discussed earlier may form the basis for this endeavor, although the nature of an instructional situation does have some unique characteristics. Theories of learning from instruction are somewhat different from regular theories of learning (Shuell, 1980), and important research on cognitive theories of learning from instruction (e.g., Lein-

[5] For a more complete discussion of this point, see Shuell and Lee (1976).

hardt & Putnam, 1986; Snow & Lohman, 1984) is beginning to appear in the literature.

With regard to prior knowledge, we know that students often begin learning with substantial misconceptions about the material they are studying (e.g., Champagne, Klopfer, & Gunstone, 1982) and that remnants of these misconceptions even persist in students who receive high grades in the course (Champagne, Klopfer, & Anderson, 1980; Gunstoke & White, 1981). Students also make systematic errors (such as always subtracting the smallest digit from the largest digit, regardless of which one is on top) sometimes referred to as "buggy algorithms" (Brown & VanLehn, 1982; Resnick, 1982). There errors are not careless mistakes or even the result of faulty reasoning; rather, they represent what students reasonably consider to be appropriate ways of dealing with the problem on which they are working, given their current knowledge structure (i.e., prior knowledge). Analysis of these errors can provide the teacher (or textbook writer, etc.) with useful insights into the type of instruction that has the best chance of being successful; at the very least, it highlights the crucial role played by prior knowledge in any real-life learning situation.

What these concerns mean is that the teacher's role is different from the one frequently envisioned in traditional conceptions of teaching. What have changed are the focus and the realization that good teachers are not merely people who can articulate a large number of relevant facts and ideas (although a sound understanding of the subject matter they are teaching is certainly essential); effective teachers must know how to get students actively engaged in learning activities that are appropriate for the desired outcome(s). This task involves the appropriate selection of content, an awareness of the cognitive processes that must be used by the learner in order to learn the content, and understanding of how prior knowledge and existing knowledge structures determine what and if the student learns from the material presented (and hopefully being studied). Consequently, we need to know more about the way in which specific content and instructional procedures engage and/or elicit the psychological processes and knowledge structures appropriate for the desired learning outcome(s) to be achieved — fortunately, some advances are beginning to be made in this direction (e.g., Winne & Marx, 1983).

Summary

The cognitive sciences have begun to give serious consideration to research on human learning, and several different theories of cognitive learning have been suggested. Although the orientation of those interested in cognitive learning differs considerably from the more traditional, behavioral orientation toward learning, there are also similarities and common concerns between the two approaches. Learning is now viewed as being active, constructive, cumulative, and goal oriented. Yet, concerns for cognitive learning do not necessarily invalidate traditional concerns of learning psychology, and for investigators who look at learning in simpler terms, many of the traditional concerns of learning research remain viable. Individual learners go about learning in different ways (Bruner, 1985), and there are different types of learning outcomes (e.g., Gagné, 1965, 1984; Rumelhart & Norman, 1978). Thus, the more traditional principles of learning may be appropriate for certain types of learning while new principles need to be forged for other types of learning, especially those more complex forms of learning in which the desired outcome involves the understanding of relationships among many separate pieces of information. The possibility of identifying and integrating these multiple aspects of learning presents an important challenge to future research on learning and its application to a variety of applied problems, including classroom learning and instruction.

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