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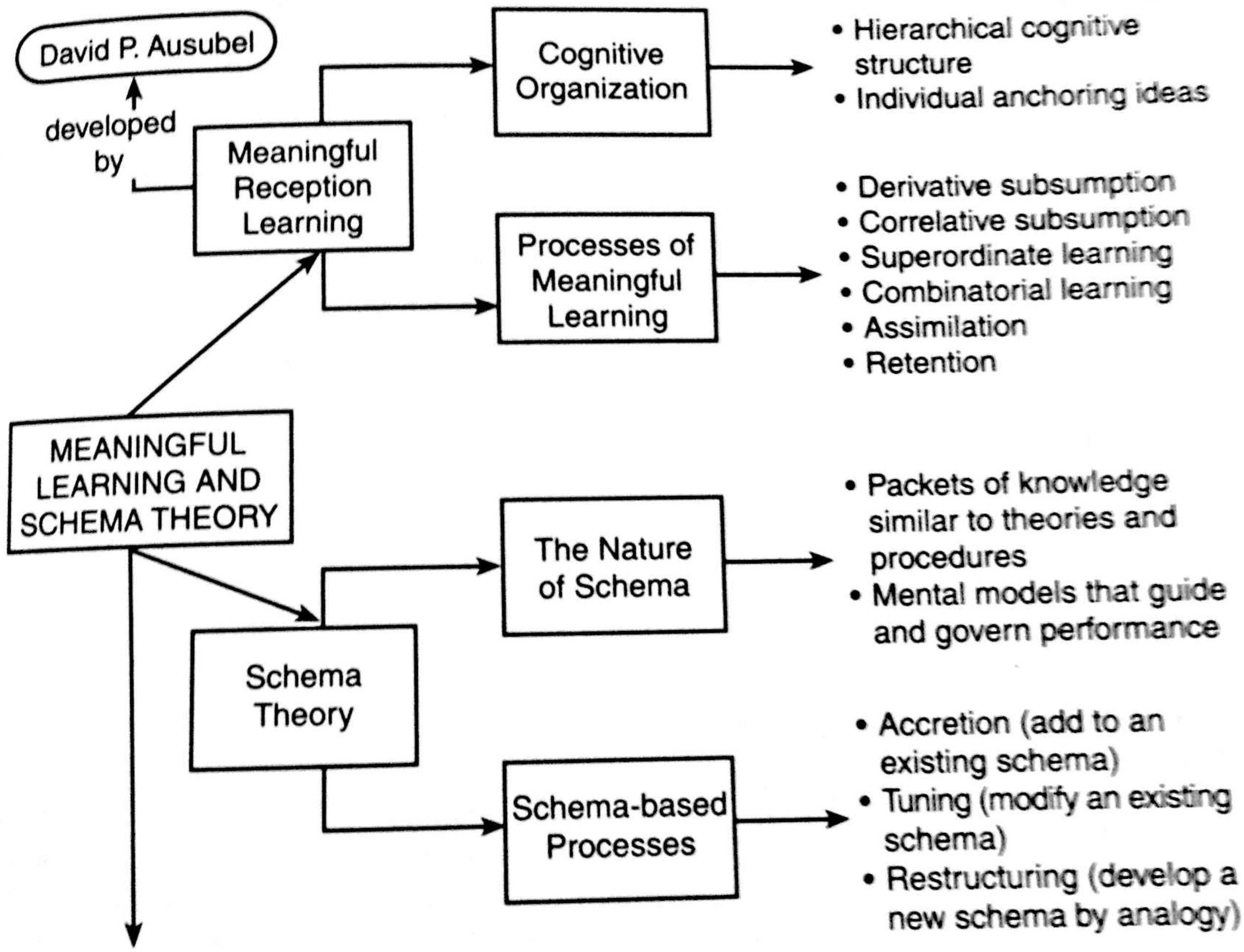
Meaningful Learning and Schema Theory



Instructional Implications

1. Activate prior knowledge using advance organizers and schema signals. Manage cognitive load.
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Consider these scenarios.

• *A Lesson on Democracy*

The place is a public school seventh grade social studies classroom. A lesson on democracy with a focus on American history has begun. The students have brainstormed a list of characteristics describing their understanding of government, and from their answers, their teacher Mr. Amaya has written a simplified definition of the term on the board. With this, the students prepare to discuss different forms of government (including oligarchy, democracy, fascism, etc.), following which they will focus on democracy and all its related concepts. Mr. Amaya presents a conceptual model to help students organize their growing knowledge about different forms and functions of government, and he tests their understanding with questions such as, "Does a vice-president or governor (member of the executive branch) have the right to keep secret who attended energy meetings and what was discussed when the results of these meeting may influence policy development by the legislature (legislative branch)? Does the Supreme Court (judicial branch) have the right to force this information to be made public?"

• *Making Mayonnaise*[1]

The study of cooking provides a useful example of the difficulty of learning complex subjects. To a noncook, the combination of ingredients in mayonnaise is not at all an obvious one. It is for this reason that it is interesting to ask naive subjects just what they expect mayonnaise to be made of:

Protocol of the experimenter (DAN) and CN, an 8-year-old girl

Dan: How do you make mayonnaise?

CN: How you make mayonnaise is you look at a cookbook.

Dan: OK, but without looking at a cookbook, can you guess what it is that's inside mayonnaise?

CN: Uh.

Dan: How would you make it?

CN: Uh, Butter—uh, let me think (5-second pause), hmmm (10-second pause), whipped cream very, very, very finely whipped so it's smooth. That's probably how you make it, just with whipped cream, very, very, very, very fine and smooth.

Dan: Anything else?

CN: You might add a little taste to it.

Dan: Taste of what?

CN: (10-second pause) Sort of a vanilla taste.

Dan: Suppose I said that mayonnaise is made from egg yolk—and oil. What would you say?

CN: I would say it's very, very wrong.

Dan: Why?

CN: You can't make mayonnaise out of eggs and water—I mean oil.

Dan: Why not?

CN: Because of taste and smoothness and stuff like that.

Protocol of the experimenter (DAN) and GB, an adult male psychology professor

Dan: How would you make something like mayonnaise?

GB: Mayonnaise? How do you make mayonnaise? You can't make mayonnaise; it has to be bought in jars. Mayonnaise. Um. You mix whipped cream with, ummm, some mustard.

[1]From Norman, Gentner, & Stevens, 1976, p. 185

Learning to make mayonnaise and learning about democracy probably seem as though they have little in common. However, both involve learning and making use of information, information that may not always be meaningful to learners, even when, as in the case of mayonnaise, the result is highly familiar.

Learning information meaningfully has roots as a field of study in the verbal learning tradition begun by Ebbinghaus (1885; see Chapter 1). Whereas Ebbinghaus believed that human learning and memory should be uncontaminated by old associations or meaning, others, such as David P. Ausubel, thought that meaning was at the very core of cognitive experience. It made no sense to Ausubel, an educational psychologist, to study learning with materials so bereft of meaning as the nonsense syllables invented by Ebbinghaus and adopted by many cognitive psychologists. Ausubel preferred to use prose, or textual materials of some length, because text passages more closely approximate the kinds of learning materials students encounter in actual classrooms.

Ausubel developed a theory of meaningful learning on a course parallel with and essentially unaffected by the cognitive information-processing theory discussed in the previous chapter. Although he regarded the human nervous system as a "data-processing and storage mechanism" (Ausubel, 1965, p. 8), Ausubel did not consider as cognitive theory the computer models of cognition being developed at the time by Newell, Simon, and Shaw (1958).

Ausubel also considered his work, at least initially, to be fundamentally different from the thrust of schema theory, which began to draw the attention of cognitive scientists at about the same time Ausubel was publishing. As the concept of schema has developed in the cognitive literature, however, it is similar to Ausubel's position, and in 1977, Richard Mayer proposed a synthesis of verbal learning research from a variety of perspectives that included schema theory and Ausubel's meaningful learning theory.

Today, Ausubel's theory is not considered particularly current, whereas the concept of schema has retained an active position in learning research and theory. Nonetheless, there are several aspects of Ausubel's meaningful learning theory that have become a standard part of educational practice. Moreover, the emphasis on understanding that characterizes Ausubel's work is gaining ground in other approaches to instruction, although with a slightly different twist. "Understanding…is knowledge in thoughtful action. This would be no more than a philosophical point if it could be taken for granted that the acquisition of knowledge brought about understanding like the caboose of a train" (Perkins & Unger, 1999, p. 95). Ausubel wrote as though he did take it for granted that understanding automatically followed knowledge. For him, that is what meaningful learning was all about. However, subsequent research has shown that transfer, or use of prior learning in new or related contexts, is by no means as assured as Ausubel might have believed.

This chapter therefore begins with Ausubel, proceeds to schema theory, and concludes with practical implications of both, with particular emphasis on teaching for understanding. This juxtaposition should help you better judge their competing claims as well as determine what these theories explain that theories presented in prior chapters do not.

Ausubel's Meaningful Reception Learning

Meaning, according to Ausubel, is not something that resides "in the text" and outside the learner. He considered textual materials, like anything else learners might experience, to be "potentially meaningful." Meaning occurs when learners actively interpret their experiences using certain internal, cognitive operations. To account for these cognitive operations and how they interact with experience to give rise to learning, Ausubel proposed a theory of meaningful, reception learning (Ausubel, 1962, 1963a, 1968; Ausubel, Novak, & Hanesian, 1978).

As a means of differentiating the types of learning that go on in typical classrooms, Ausubel (1961, 1963b) made two important distinctions. First, he distinguished between reception and discovery learning, a distinction he considered important because he contended that most school learning is of the reception type. In reception learning, Ausubel (1961) stated, "the entire content of what is to be learned is presented to the learner in its final form" (p. 16). The learner is therefore required to internalize the information in a form that will be available for later use. In discovery learning, on the other hand, learners are required to "rearrange a given array of information, integrate it with existing cognitive structure, and reorganize or transform the integrated combination in such a way as to create a desired end product or discover a missing means-end relationship. After this phase is completed, the discovered content is internalized just as in reception learning" (Ausubel, 1961, p. 17).

Reception learning, then, is essentially the same as what commonly occurs in expository instruction, where learners are told information rather than discovering it for themselves. Science textbooks, for example, state principles (often with a description of the research conducted to arrive at these principles) and provide examples of their application. From the principle's definition and examples, along with practice in its application, students are expected to understand what it means. By contrast, science teachers often facilitate discovery learning by having students conduct experiments from which they derive their understanding of scientific principles.

Although discovery learning methods certainly have a place in instruction (e.g., in laboratories or everyday problem solving) (see also discussions in Chapter 7 and Chapter 11), Ausubel believed that such methods "hardly constitute an efficient *primary* means of transmitting the *content* of an academic discipline" (Ausubel et al., 1978, p. 26, emphases theirs).

The second distinction made by Ausubel (1961, 1963b) and Ausubel et al. (1978) is between rote and meaningful learning. Rote learning is the same as verbatim memorization, and to Ausubel, that means the learner has made no real connection between what was already known and what was memorized. What was memorized stands as an arbitrary piece of information in isolation from the rest of cognitive structure. Children frequently memorize the Pledge of Allegiance, for example, and cannot tell you what the pledge means. By contrast, meaningful learning refers to the process of relating potentially meaningful information to what the learner already knows in a nonarbitrary and substantive way. This means that, in the previous example, the children would have some notion as to what the flag means as a symbol of the United States. With this prior knowledge, they can construct an understanding of what is entailed by pledging allegiance.

It is important to realize, said Ausubel, that either rote or meaningful learning can occur in reception and discovery learning situations. Students may attempt to memorize the results of a science experiment, for example, instead of understanding what the results suggest about the principle under study. Likewise, in reception learning, just because the learner is in a position of receiving information does not mean the learner must be passive. Quite the contrary, meaningful reception learning implies that the learner is cognitively active.

Three conditions are essential to meaningful learning. One is that the learner must employ a meaningful learning set to any learning task. If the learner intends to memorize, then meaningful learning will not result, no matter whether learning is by reception or by discovery. A second essential condition is that the material to be learned must be potentially meaningful. This suggests that learning tasks and materials should be organized, readable, and relevant, so that learners do not fail to learn because they can make no sense of the learning task. Finally, the third and most important condition for meaningful learning is what learners already know and how that knowledge relates to what they are asked to learn. According to Ausubel (1963b), "existing cognitive structure, that is, an individual's organization, stability, and clarity of knowledge is the principal factor influencing the learning and retention of meaningful new material" (p. 217). Given the importance Ausubel placed on prior knowledge in learning, how did he conceive of memory structure?

Cognitive Organization in the Learner

"The model of cognitive organization proposed for the learning and retention of meaningful materials assumes the existence of a cognitive structure that is hierarchically organized..." (Ausubel, 1963b, p. 217). As indicated earlier, Ausubel acknowledged the existence of neurophysiological events underlying learning, but he expressed his theory in terms of hypothetical constructs of memory structure and learning processes. He proposed **cognitive structure** as the learner's *overall memorial structure or integrated body of knowledge.* This cognitive structure is made up of sets of ideas that are organized hierarchically and by theme. Moreover, within any given hierarchy, the most inclusive ideas are the strongest and most stable. Except for its emphasis on a hierarchy of ideas, this structure is similar to those proposed by the propositional model of memory that was discussed in the previous chapter.

For an example of cognitive structure, consider what you know about cooking that might be relevant if you were learning how to make mayonnaise. You know that cooking involves mixing together ingredients that might be known by heart or listed in a recipe. Generally, the ingredients must be mixed in a particular order, and certain types of mixing might be used, such as "stir until moistened," "beat until firm," and "whip until smooth." Mixing might also require different types of implements, such as a spoon, fork, whisk, or electric mixer. Figure 4.1 displays a partial hierarchy that might represent this knowledge about cooking. According to Ausubel, the general ideas high in the hierarchy (e.g., "cooking involves preparation") would be more stable and therefore more easily remembered than specific ideas low in the hierarchy (such as the type of implement best used for beating).

The cognitive structure provides an overall framework into which new knowledge will be incorporated, but to describe how specific linkages occur, Ausubel proposed the notion of anchoring ideas. **Anchoring ideas** are the *specific, relevant ideas in the learner's cognitive structure that provide the entry points for new information to be connected.* They are what enable the learner to construct meaning from new information and experiences that are only potentially meaningful.

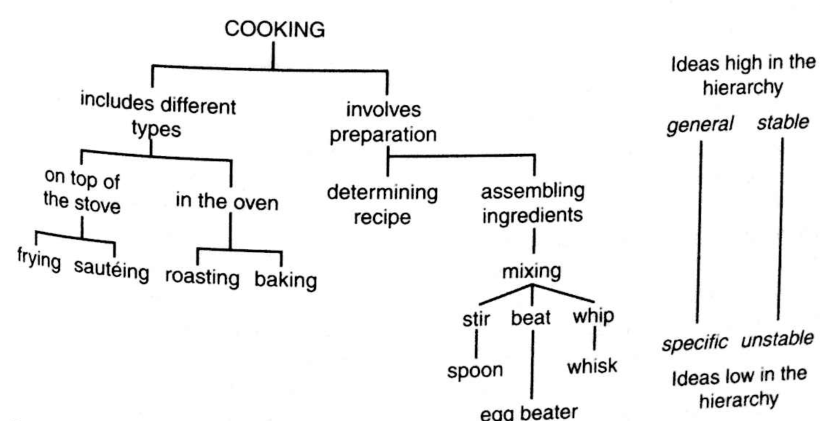


FIGURE 4.1 ***A Partial Hierarchy of Knowledge about Cooking***

For example, the most relevant anchor GB can think of in the Making Mayonnaise scenario is the jar of mayonnaise that he has probably taken out of the refrigerator countless times. Like GB, CN doesn't know the ingredients of mayonnaise or how to make it, and the most relevant anchor that came to her mind was "cookbook." Even when she is told the ingredients, however, her reaction is disbelief, most likely because she has no anchor that is specifically relevant to making mayonnaise. After all, how many ingredients might she have direct experience with that take on completely different perceptual characteristics when they are mixed together?

Cognitive structure and specific anchoring ideas within the cognitive structure, then, are prerequisites to meaningful learning. They describe the memory structure within which new knowledge will be integrated. But we have yet to see how the processes of learning occur, i.e., how the new knowledge is actually connected with and incorporated into the learner's existing knowledge.

Processes of Meaningful Learning

If memory is actually organized in the fashion that Ausubel proposed, then how is new information likely to be added to an existing structure? There are three possible ways: New information can be subordinate to (lower in the structure), superordinate to (higher in the structure), or coordinate with (at the same level in the structure) an existing idea. Consistent with each of these ways, Ausubel proposed a process of learning.

Derivative and Correlative Subsumption. The principal way of adding information to cognitive structure, in Ausubel's view, is to attach new ideas and details in a subordinate fashion to the anchoring ideas already present. This is the process Ausubel called subsumption (Ausubel, 1962, 1963a, 1968; Ausubel et al., 1978). That is, *new, incoming ideas are* ***subsumed*** *under more general and inclusive anchoring ideas already in memory.* Another way to think of subsumption is to consider the anchoring ideas as hooks that snag those incoming details and modifiers pertaining to them.

Because incoming details can relate to anchoring ideas in two possible ways (both still subordinate), subsumption is said to occur in two ways. **Derivative subsumption** refers to the *learning of new examples or cases that are illustrative of an established concept or previously learned proposition.* If we consider A in Figure 4.2 to be the anchoring idea in a learner's cognitive structure, with examples a1, a2, and a3 associated in a subordinate fashion, then new example a4 will be derivatively subsumed under A.

For example, if A is the general concept, dog, and collies, cocker spaniels, and poodles are known as examples, then it is relatively easy to learn the example, whippet, and subsume that information under the general con-

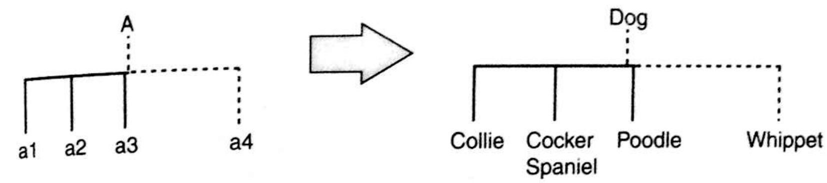


FIGURE 4.2 ***An Example of Derivative Subsumption***

cept. The criterial attributes of the concept A remain unchanged; simply, new examples are recognized as relevant (see Figure 4.2).

Other instances of derivative subsumption include learning in geography that Texas and India are both places where rice is grown. Or in law, cases may be found that were all decided based on the same legal precedent. Finally, a teacher or instructional designer might encounter numerous examples where a particular principle of learning has been employed.

More typical of the way most learning occurs, according to Ausubel, is **correlative subsumption.** This process refers to the *elaboration, extension, or modification of the previously learned concept or proposition by the subsumption of the incoming idea.* Instead of simply adding a new example, then, the new information adds a new characteristic or feature to the existing idea. In so doing, it interacts with the existing idea to change the learner's understanding of it in some way. The original A becomes A' as shown in Figure 4.3.

For example, suppose A represents the concept positive reinforcement in an education student's cognitive structure of behavioral management. The student knows that positive reinforcement increases behavior (attribute u) through the presentation of a reinforcer (attribute v) that is contingent upon the desired response (attribute w). When the student now learns that the reinforcer can be a high-frequency behavior (new attribute x), his or her understanding of positive reinforcement has now been extended to include the special circumstances surrounding the Premack principle. The criterial attributes of the concept have been modified. As indicated above, A has also

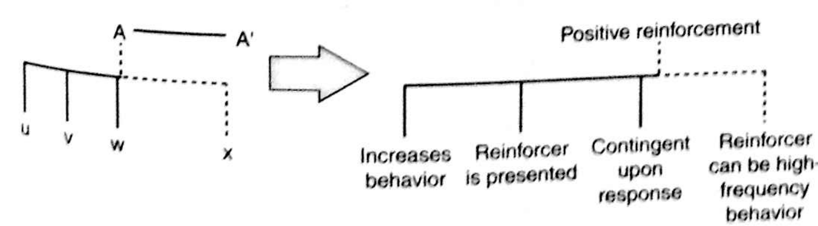


FIGURE 4.3 ***An Example of Correlative Subsumption***

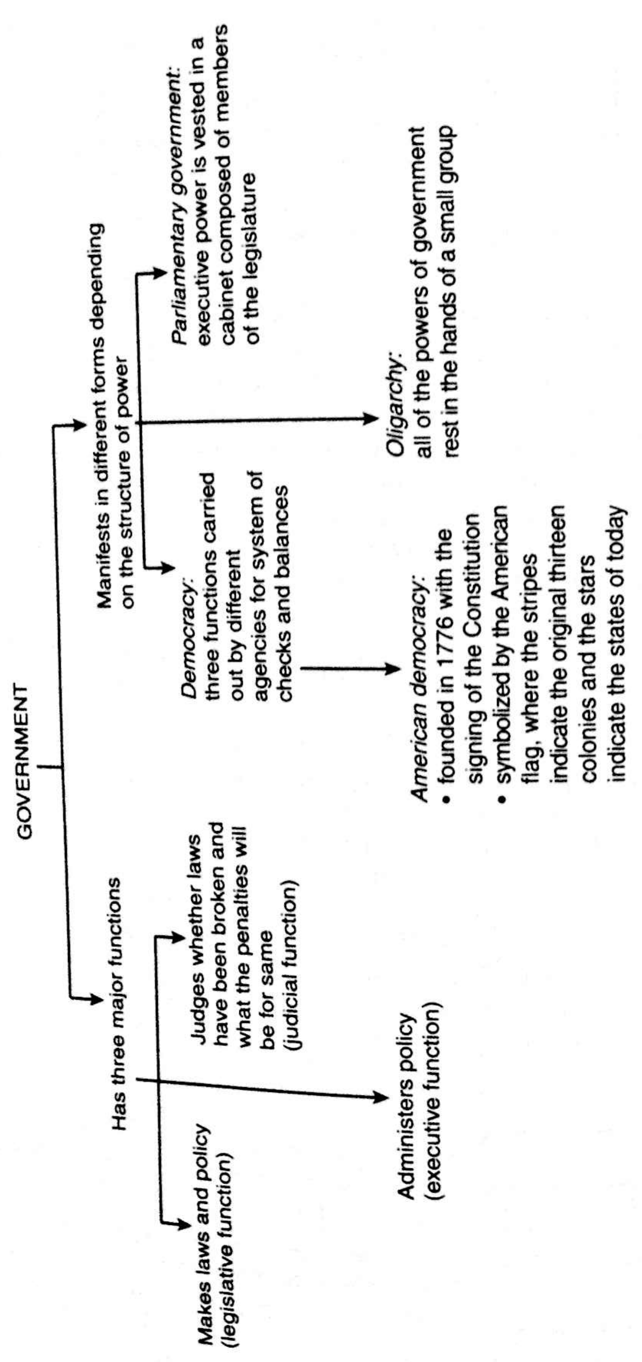


FIGURE 4.4 *A Cognitive Structure about Democracy Learned through Subsumption*

been replaced by A', because the student's understanding of the positive reinforcement principle is no longer the same as it was.

Examples of correlative subsumption can also be readily seen in the content being taught by Mr. Amaya in his social studies class. As the students learn about different aspects of government, they correlatively subsume these characteristics under the inclusive concept, government. (They may also derivatively subsume the labels, democracy and oligarchy, for example, under the label, government.) Then when discussion turns to expressions of patriotism, for example, such as displaying the American flag to commemorate the founding of America's democracy, students correlatively subsume this information under the anchoring idea of democracy (Figure 4.4).

Superordinate and Combinatorial Learning. Not all learning can be explained through the processes of derivative and correlative subsumption, because not all learning occurs in a subordinate fashion. In discovery learning, for instance, students may be working with examples to discover the more general concept or proposition. Thus, learning must be occurring in a superordinate, rather than subordinate, way. Similarly, what about instances in which students learn about similar concepts at the same level in the hierarchy as the anchoring idea? Learning in that case must be neither subordinate nor superordinate, but coordinate, or lateral. To account for learning that is not subordinate in nature, Ausubel, et al. (1978) proposed the processes of superordinate and combinatorial learning.

Superordinate learning occurs through a synthesis of established ideas. That is, a *new, inclusive proposition or concept is learned under which already established ideas can be subsumed.* If ideas x, y, and z are already established in the learner's cognitive structure and their association is discovered, then new idea A is learned under which they are all subsequently subsumed, as shown in Figure 4.5.

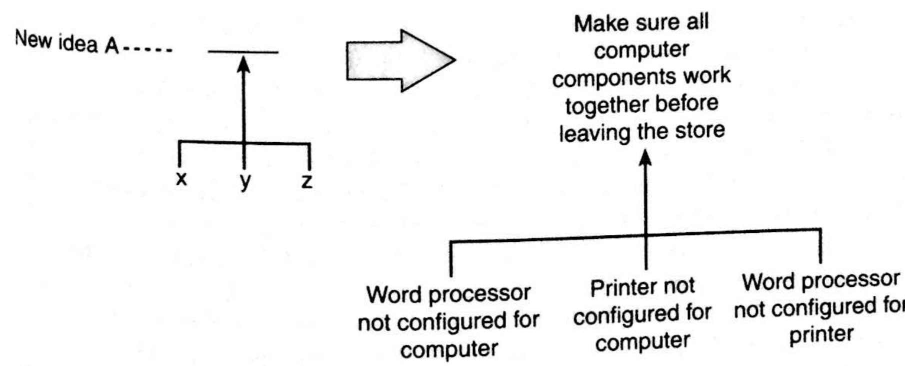


FIGURE 4.5 *An Example of Superordinate Learning*

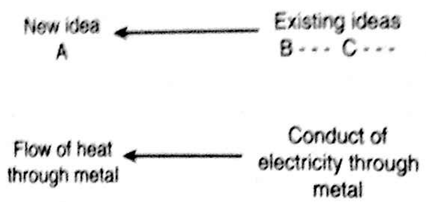


FIGURE 4.6 ***An Example of Combinatorial Learning***

An example of subordinate learning is evident in my experience with purchasing my first home computer. At the time, I knew virtually nothing about microcomputers except that I wanted one with which to do word processing. A slick salesman sold me a computer with monitor, word-processing package, and dot matrix printer. I took it all home, hooked it all up, and nothing worked. To make a long story short, the word processor was not configured for the computer (event x); it was adjusted. The printer did not work with the computer (event y); a different printer card solved the problem. The word processor was not compatible with the printer (event z); the designers of the word processor never could figure this one out, so I sold the printer. What did I learn (new idea, A) from these events? Make sure all components of the system work together before leaving the store!

When new concepts or propositions are neither more inclusive of nor subordinate to relevant anchoring ideas in the cognitive structure, they are meaningfully learned in a combinatorial way. In other words, **combinatorial learning** occurs when *the new idea is not relatable in a specific sense to an existing anchor but is generally relevant to a broad background of information*, which may contain a number of similar ideas sharing criterial attributes, as shown in Figure 4.6.

An example of combinatorial learning can be seen in the relationship between the flow of heat and the conducting of electricity through metals. Heat flow and electrical conductivity are not specifically related, in a subordinate or superordinate sense. Yet to understand each, a learner must have some previous knowledge of how metals are structured. Moreover, since the processes are analogous, having already learned about how heat flows through metals can facilitate understanding how electricity is conducted and vice versa (cf. Royer & Cable, 1975; Royer & Perkins, 1977; Driscoll, 1985).

Concepts exist in most subject matter disciplines that are coordinate to one another. And even though many coordinate concepts are also subordinate to some inclusive idea, their relationships to one another must be learned as well as their relationships to the subsuming idea. To take the government example again, democracy, oligarchy, and fascism all bear a coordinate relationship to one another. Thus, learning about one can provide a general background of information, which may be useful in learning the others. Ausubel and Fitzgerald (1961) found, for example, that knowing a lot about Christianity aided learners in acquiring new knowledge about Buddhism. Like the types of government in the previous example, these types of religion bear a coordinate relationship to each other, appropriate to combinatorial learning. According to Ausubel et al. (1978), "Most of the *new* generalizations that students learn in science, mathematics, social studies, and the humanities are examples of combinatorial learnings, for example, relationships between mass and energy, heat and volume, genic structure and variability, demand and price" (p. 59).

Assimilation Theory. By 1978, Ausubel had adopted the label assimilation theory to describe the meaningful learning processes of subsumption, superordinate learning, and combinatorial learning. In earlier versions of the theory (Ausubel, 1963a, 1968), assimilation referred primarily to the process of retention, whereby new information tends to be reduced to (or assimilated by) the meaning of the stable, more established anchoring idea. Although Ausubel's notions of what happens in retention changed little, which will be discussed in the next section, he came to use the concept of assimilation more broadly. Taking together learning and retention, "The result of the interaction that takes place between the new material to be learned and the existing cognitive structure is an *assimilation* of old and new meanings to form a more highly differentiated cognitive structure" (Ausubel et al., 1978, pp. 67–68).

Retention of Meaningful Learning

As indicated earlier, retention involves maintaining the availability of acquired information so that it may be accessed for use at a later time. Immediately following initial meaningful learning, new information is easily accessible, its stability enhanced by virtue of its anchorage to relevant concepts in the cognitive structure (Ausubel, 1963b). Over time, because it is more economical to remember a single inclusive concept than a large number of specific details, subsumed ideas become less and less distinguishable, or dissociable, from the inclusive anchor. When they can no longer be retrieved as entities separate and distinct from the anchoring idea, they are said to be forgotten.

Ausubel believed the consequences of forgetting are far more serious for correlative, superordinate, and combinatorial learning than for derivative learning (Ausubel et al., 1978). It is probably immaterial, for instance, if a particular example of dog or rice-growing place learned through derivative subsumption cannot be remembered. But suppose not enough about standard deviation is recalled to enable the learner to reconstruct the formula for its calculation. Since correlatively subsumed details should have modified the learner's overall understanding of the concept, forgetting them to this degree would be a true loss of knowledge.

Finally, it is important to note the difference between forgetting after rote learning and forgetting after meaningful learning. Despite the fact that information in both cases becomes irretrievable, there is still a net gain in the cognitive structure following meaningful learning. The concept or proposition that provided anchorage for meaningful learning is generally more differentiated than it was previously. Thus, as Ausubel (1963b) put it, there is "memorial residue of ideational experience," which enables the concept or proposition to be "more functional for future learning and problem-solving occasions" (p. 218).

Readiness for Learning

In the generally accepted sense of the term, learning readiness refers to a learner's developmental level of cognitive functioning. It is this cognitive maturity that is assumed to determine the extent to which learners are capable of learning at various levels of abstraction within a subject matter discipline. While not discounting the impact this type of readiness may have on learning, Ausubel (1963b) and Ausubel et al. (1978) emphasized readiness as a function of previously acquired subject matter knowledge. "If [Ausubel] had to reduce all of educational psychology to just one principle, [he] would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (Ausubel et al., 1978, p. 163).

Readiness in this sense, then, depends upon both the substantive content in the learner's cognitive structure and its organizational properties. In the first place, experts in a subject matter simply have a lot more extant knowledge than do novices in the subject. The idea that extensive background knowledge facilitates subsequent learning has been consistently demonstrated (e.g., Ausubel & Fitzgerald, 1961, 1962; Tobias, 1976; Glaser, 1984). But the organization of knowledge also influences subsequent learning.

> If cognitive structure is clear, stable, and suitably organized, accurate and unambiguous meanings emerge and tend to retain their dissociability strength or availability. If, on the other hand, cognitive structure is unstable, ambiguous, disorganized, or chaotically organized, it tends to inhibit meaningful learning and retention. (Ausubel et al., 1978, p. 164)

It follows from the previous argument that learners with poorly organized cognitive structures in a subject matter should be aided in learning by materials that make clear similarities and differences among concepts to be

learned. In fact, early studies conducted by Ausubel and his associates (e.g., Ausubel & Fitzgerald, 1961; Ausubel & Youssef, 1963) provided evidence that this was true. When learners already possessed organized and stable cognitive structures, however, such materials made no difference in what else they learned (Ausubel & Fitzgerald, 1961).

Royer, Perkins, and Konold (1978) provided evidence of a different sort to support Ausubel's claim that cognitive organization influences learning. They gave students passages to read, labeled with either the name of a fictitious person or the name of a famous person (e.g., Adolf Hitler). After studying the information, students rated sentences as to whether the sentences were old (i.e., from the passage) or new (i.e., never seen before). Subjects' judgments were quite accurate when the passage they read was ostensibly about a fictitious person. Having no anchoring information into which to meaningfully subsume the new information, students essentially learned the new ideas by rote. When they thought the information was about Adolf Hitler, however, learners typically had prior knowledge about Hitler to which they could attach the new ideas. As a result, they tended to misidentify as "old" sentences that were new but were thematically related to Hitler, such as, "He hated and persecuted the Jews."

To be ready for learning new material, then, learners of all sorts must possess a relevant, stable, and organized cognitive structure. Ausubel acknowledged, however, two additional influences on readiness that are important to mention. The first has to do with age differences among learners, and the second concerns culturally diverse learners.

According to Ausubel et al. (1978), "the cognitive organization of children differs mainly from that of adults in containing fewer abstract concepts, fewer higher order abstractions, and more intuitive-nonverbal than abstract-verbal understandings of many propositions" (p. 140). This simply means that children have a greater reliance during learning on concrete-empirical experience. Perhaps more so than adults, then, children should be taught in concrete ways. By extension, adults should be taught concretely when they know very little about the subject matter.

Accounting for the effects of culture on learning, Ausubel claimed, can be done within the same theoretical framework established for learning in general. That is, children who are culturally diverse relative to their classmates have different cognitive structures owing to the differences in their life experiences and prior learnings. This means that some learning tasks are likely to exceed the cognitive readiness of these children (Ausubel et al., 1978). What should be done about it? According to Ausubel, the basic principles underlying appropriate teaching strategies are essentially the same, regardless of who the learners are. To repeat the principle he considers most important: Ascertain the cognitive structures of your learners and teach accordingly. How one might do this most effectively is discussed next.

Meaningful Learning as Assimilation to Schema

Although "Ausubel's thinking about the role of abstract knowledge structures in learning from text generally was on the right track," Anderson, Spiro, and Anderson (1978, p. 439) found the theory of meaningful learning vague and inconclusive. They claimed that schema theory could bring precision to Ausubel's ideas.

Most modern cognitive conceptions of schema harken back to Bartlett (1932). In a study investigating the nature of remembering over a long period of time, Bartlett used the term *schema* to mean an organizing and orienting attitude that involves active organization of past experiences. Bartlett found that his subjects' recall of "War of the Ghosts" contained inaccuracies that could be directly related to their own interests and attitudes. He theorized that they invoked a relevant schema for understanding the story, and then, at recall, reconstructed in accord with the schema details about the story that they had forgotten.

Ausubel et al. (1978) acknowledged a similarity between anchoring ideas and Bartlett's notions of schema, but then they dismissed Bartlett's position as being fundamentally different from Ausubel's. Schemata are perceptually based, they argued, whereas anchoring ideas are cognitive. Bartlett theorized about the reconstructive nature of retention; Ausubel was interested in the constructive nature of learning. Ausubel et al. (1978) suggested that recall is really not reconstructing original meanings, it is reproducing information that has undergone memorial reduction.

When Anderson et al. (1978) suggested that the concept of schema might clarify Ausubel's theory, they took a fundamentally cognitive approach, conceiving of schema as a generic characterization of things and events. Thus, "to interpret a particular situation in terms of a schema is to match the elements in the situation with the generic characterizations in the schematic knowledge structure. Another way to express this is to say that schemata contain *slots* or placeholders that can be *instantiated*... with certain particular cases" (Anderson et al., 1978, p. 434; emphasis in original).

As an example, consider how CN's and GB's knowledge about cooking in the Making Mayonnaise scenario can be reinterpreted in terms of a schema. A "cooking" schema is likely to have slots for details about cooking, such as what utensils are used, what types of mixing could be employed, and so forth. To the extent that individuals have had experience cooking different things, these slots may be filled, or instantiated, with particular information. CN's and GB's responses to the question of how to make mayonnaise are evidence that they have not experienced beating eggs and oil together. Because of this, their schema about mayonnaise itself is based on perceptual features such as taste and consistency. This incomplete schema leads them to incorrect expectations about what mayonnaise is made of and how it is made.

A Lesson on Democracy can also be interpreted in terms of schema theory. That is, the seventh graders in Mr. Amaya's class are acquiring a government schema that will eventually enable them to instantiate details about different types of governments. According to Anderson et al. (1978), schema theory enables one to predict learning from textual materials, because "the schemata a person already possesses are a principal determiner of what will be learned from a text" (p. 438).

Efforts Toward an Understanding of Schema

Notions about the nature and function of the schema developed from several lines of research that were all focused on the impact of prior knowledge on comprehension and memory. Many studies demonstrated that what is remembered is largely a function of what was understood to begin with. But studies also revealed that both comprehension and memory are driven by meaning, or gist. Consider the following sentences, for example:

> The house was in the valley.
> The house was little.
> The valley was green.
> The house burned down.

If asked to read and later recall these sentences from memory, you are likely to produce the following response: "The little house in the green valley burned down" (Bransford & Franks, 1971). Rather than store sentences separately in memory, it appears that learners construct and store the gist of the sentences together.

Likewise, learners comprehend and remember information better when they can relate it to a familiar theme. For example, read the following passage:

> The procedure is actually quite simple. First you arrange items into different groups. Of course one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities that is the next step; otherwise you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than too many. In the short run this may not seem important but complications can easily arise. A mistake can be expensive as well. At first, the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then, one never can tell. After the procedure is completed one arranges the materials into different groups again. Then they can be put into their appropriate places.

> Eventually they will be used once more and the whole cycle will then have to be repeated. However, that is part of life. (Bransford, 1979, pp. 134–135)

None of the sentences in the above paragraph seems particularly difficult to understand, but together they do not make much sense. Bransford and Johnson (1972, 1973) and Dooling and Lachman (1971) found that without benefit of the theme, "washing clothes," subjects had difficulty comprehending and remembering the passage. Similar effects also have been demonstrated with pictures providing the theme (Bransford & Johnson, 1972), and Bransford (1979) argued that appropriate verbal knowledge can support the understanding of physical features of stimuli as well. For example, the flat blades of a dressmaker's shears might go unnoticed without the knowledge that they enable cutting on a flat surface. Finally, new, thematically consistent information is often falsely recognized as having been previously presented (Sulin & Dooling, 1974; Royer, Perkins, & Konold, 1978). This phenomenon was discussed earlier in the chapter as providing evidence for meaningful learning. Recall that learners are assumed to integrate new information within a related cognitive structure. "Remembering" information that was inferred rather than actually experienced has also been taken as evidence of active brain processes (National Research Council, 2000) and suggests a link to research discussed in Chapter 8.

In addition to gist and theme, the amount of prior knowledge possessed by learners and their interests can affect their interpretation and recall of information as well as their ability to solve problems. Chiesi and co-workers (Chiesi, Spilich, & Voss, 1979; Spilich et al., 1979) demonstrated that subjects who knew a lot about baseball were able to remember much more from a summary of a baseball inning than were subjects who knew little about the game. Similarly, Chi (1978) replicated the results of Chase and Simon (1973a, 1973b) with findings that expert chess players outperformed novices at recalling the positions of chessmen on the board. Finally, Anderson (1977) reported a study in which an ambiguous passage that could be interpreted in terms of playing cards or playing music was read to music students. As might be expected, students with an interest in music interpreted the passage to be about music and were unaware that the passage could be interpreted any other way.

This effect of perspective on learning and memory was also demonstrated by Pichert and Anderson (1977) and Anderson and Pichert (1978). In their studies, individuals were asked to read a passage describing two boys playing in front of a house. Half the subjects were told to read the story from the perspective of a real estate agent, while the other half were to adopt the perspective of a burglar. As predicted, perspective affected recall. That is, the real estate agent subjects remembered details about the number of rooms and condition of the house, whereas the burglar subjects remembered details about valuable objects and the isolation of the house from surrounding neighbors. But there was an unexpected finding as well. When asked to adopt the alternate perspective, without rereading the story, subjects remembered information that they did not report the first time! How was this notion of perspective to be explained in theories of memory? The answer to this, and indeed the way to incorporate the results of all these studies of prior knowledge, was found in schema theory.

The Nature of Schema

A schema is "a data structure for representing the generic concepts stored in memory" (Rumelhart, 1980, p. 34). Schemata are packets of knowledge, and schema theory is a theory of how these packets are represented and how that representation facilitates the use of the knowledge in particular ways. Thus, there are schemata "representing our knowledge about all concepts: those underlying objects, situations, events, sequences of events, actions, and sequences of actions" (Rumelhart, 1980, p. 34). To illustrate these various aspects of schemata, Rumelhart presented four different analogies.

First, schemata are like plays, in that a schema has variables that can be associated with different aspects of the environment, just as a play has characters, settings, actions, and so forth. Suppose, for example, that a playwright has written a very simple play about beating egg yolks in order to make mayonnaise. There must be a person to do the beating, an implement that person will use, a container for the eggs, and an overall setting in which the action will occur. Rumelhart would argue that our schema for egg-beating is very much like this description. And when the playwright specifies who will do the beating, what implement will be used, and where the action will take place, this amounts to the same process as schema instantiation. In other words, the schema variables take on specific values. Moreover, these values are typically constrained. Only certain tools are used to beat eggs, for example, and egg-beating generally takes place only in kitchens.

Schemata are like theories. Theories enable us to interpret events and phenomena surrounding us. To the extent that our theories work, they also allow us to make predictions about unobserved events. So it is with schemata. "The total set of schemata instantiated at a particular moment in time constitutes our internal model of the situation we face at that moment in time" (Rumelhart, 1980, p. 37). In addition, schemata provide the basis for making inferences about unobserved events. Consider the egg-beating event, for example. If you read a description of someone beating eggs that never mentioned what tool was being used, your egg-beating schema would fill in that gap with the default value (cf. Minsky, 1975) for egg-beating implement. Asked later what tool was used to beat the eggs, you are likely to reply, "Oh, an egg beater, hand mixer, something like that...." Default values are our initial guesses for variables whose values have not yet been observed.

While plays and theories are passive, schemata are active, so that schemata are like procedures, such as computer programs. They actively evaluate incoming information for the quality of fit, and they may involve a network of subprocedures. For example, the egg-beating schema undoubtedly has a subschema for how hard and how long to beat for given purposes. Schemata such as these that direct one's actions in a given situation have come to be called scripts. Finally, schemata are like parsers, in that they break down and organize incoming information to fit appropriate schema structures.

Because schemata are active in influencing how people interpret events and solve problems, they have also been conceived as mental models. Mental models are schemata that not only represent one's knowledge about specific subject matter, but also include perceptions of task demands and task performances. Thus, mental models are schemata that guide and govern performance as one undertakes some task or attempts to solve some problem.

Norman (1983) made the following observations about mental models (p. 8):

1. Mental models are incomplete.
2. People's ability to control their models is limited.
3. Mental models are unstable.
4. Mental models do not have firm boundaries.
5. Mental models are unscientific.
6. Mental models are parsimonious.

What this means is that people bring to tasks imprecise, partial, and idiosyncratic understandings that evolve with experience. Additionally, these understandings are utilitarian for the most part, rather than necessarily accurate.

As an illustration of a mental model in action, consider this brief description provided by Norman (1983). He observed people using handheld versions of several types of calculators and questioned them about their methods and understanding of the calculator.

> One of the subjects I studied (on a four-function calculator) was quite cautious. Her mental model seemed to contain information about her own limitations and the classes of errors that she could make. She commented, "I always take extra steps. I never take short cuts." She was always careful to clear the calculator before starting the problem, hitting the clear button several times. She wrote down partial results even when they could have been stored in the machine memory. (Norman, 1983, p. 8)

In trying to describe subjects' mental models of calculators, Norman speculated that most develop a rule to hit the clear button excessively because the action is functional across all kinds of calculators. The rule enables generalization to occur and thus makes the mental model work in a variety of situations. Note that the model is not accurate for all calculators, since some require only one press of the clear button to clear all registers.

Schema-Based Processing

How do schemata or mental models function to influence information processing? At the least, schema theory must deal with how schemata and mental models are acquired in the first place, how they are elaborated and modified through experience, and how they are selected and used in a processing task. Let us first consider selecting and using schemata in the face of various tasks.

Comprehending Text. Rumelhart (1980) described how readers construct interpretations of the following brief passage:

> Business had been slow since the oil crisis. Nobody seemed to want anything really elegant anymore. Suddenly the door opened and a well-dressed man entered the showroom floor. John put on his friendliest and most sincere expression and walked toward the man. (p. 43)

Sentence by sentence readers appear to invoke and evaluate schemata for their relevance to the story and ability to account for the available facts. So, for example, a business schema is selected with the first sentence, which suggests hypotheses about what is being sold. Encountering the word *elegant* in the second sentence causes readers to modify their interpretation; perhaps people do not want to buy large, elegant cars. *Showroom* is consistent with the car-selling schema, so that *well-dressed* signals money and buyer schemata, and so on. You can see the interaction between bottom-up and top-down processing that occurs in schema theory accounts of processing. An incoming stimulus activates a schema (bottom-up), which, by virtue of its variables, sets up expectations (top-down) for additional information as to the values of these variables. To the extent these expectations are met, that schema is instantiated. Information contrary to expectation, however, leads to alternate schema activation or modification of the current schema.

Comprehending lengthy texts is likely to involve not only activating and instantiating specific schemata, but also organizing those schemata into complex mental models. Johnson-Laird (1983) used the following illustration to demonstrate. Excerpted from Arthur Conan Doyle's (1905) story, "The Adventure of Charles Augustus Milverton," is this account of how Sherlock Holmes and Dr. Watson set out to burgle the house of a blackmailer, "the worst man in London."

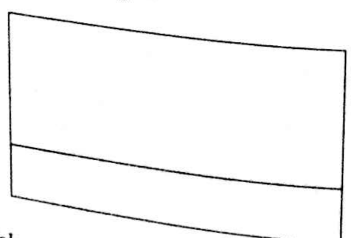
> With our black silk face-coverings, which turned us into two of the most truculent figures in London, we stole up to the silent, gloomy house. A sort of tiled veranda extended along one side of it, lined by several windows and two doors.

"That's his bedroom," Holmes whispered. "This door opens straight into the study. It would suit us best, but it is bolted as well as locked, and we should make too much noise getting in. Come round here. There's a greenhouse which opens into the drawing room."

The place was locked, but Holmes removed a circle of glass and turned the key from the inside. An instant afterwards he had closed the door behind us, and we had become felons in the eyes of the law. The thick, warm air of the conservatory and the rich, choking fragrance of exotic plants took us by the throat. He seized my hand in the darkness and led me swiftly past banks of shrubs which brushed against our faces. Holmes had remarkable powers, carefully cultivated, of seeing in the dark. Still holding my hand in one of his, he opened a door, and I was vaguely conscious that we had entered a large room in which a cigar had been smoked not long before. He felt his way among the furniture, opened another door, and closed it behind us. Putting out my hand I felt several coats hanging from the wall, and I understood that I was in a passage. We passed along it, and Holmes very gently opened a door upon the right-hand side. Something rushed out at us and my heart sprang into my mouth, but I could have laughed when I realized that it was the cat. A fire was burning in this new room, and again the air was heavy with tobacco smoke. Holmes entered on tiptoe, waited for me to follow, and then very gently closed the door. We were in Milverton's study, and a portiere at the farther side showed the entrance to his bedroom.

It was a good fire, and the room was illuminated by it. Near the door I saw the gleam of an electric switch, but it was unnecessary, even if it had been safe, to turn it on. At one side of the fireplace was a heavy curtain which covered the bay window we had seen from the outside. On the other side was the door which communicated with the veranda. A desk stood in the centre, with a turning-chair of shining red leather. Opposite was a large bookcase, with a marble bust of Athene on the top. In the corner, between the bookcase and the wall, there stood a tall, green safe, the firelight flashing back from the polished brass knobs upon its face.

Below is a simple plan of the house with the veranda running down one side of it. Which way did Holmes and Watson make their way along the veranda—from right to left, or from left to right?



According to Johnson-Laird (1983), about one in a hundred people can spontaneously give the right answer to this question. Upon rereading the passage with the question in mind, most people can answer it correctly. This suggests two conclusions. (1) There appear to be different levels of comprehension, perhaps governed by task requirements. Reading for pleasure may result in only partial representations of passage information. (2) In order to make the required inference about Holmes' and Watson's direction, one must construct a mental model of the spatial layout. (The solution, by the way, can be found at the end of the chapter.)

Understanding Events and Guiding Actions. Schemata also guide human actions as people find themselves in situations in which they must interpret what is going on and respond appropriately. Schank and Abelson (1975, 1977) investigated what they termed the "restaurant script," or what people know about restaurants and how to behave in them.

The restaurant script contains information about what it is like to go to a restaurant. There are roles to be filled (customer, waiter/waitress, cashier), certain props (such as table, menu, food, check, or tip), and certain activities (sitting down, ordering, paying the bill, tipping, and so on). This general script is also likely to vary depending upon the type and location of the restaurant. For example, fast-food restaurants differ in predictable ways from five-star restaurants, and restaurant customs in the West are likely to differ from those of other cultures.

Several studies (e.g., Anderson, Spiro, & Anderson, 1978; Bower, Black, & Turner, 1979) demonstrated that such a restaurant script served as the context for understanding and remembering information from stories taking place in restaurants. Subjects used their general knowledge about restaurants to comprehend particular events described in the stories. But now consider a story such as the following:

> Jim went to the restaurant and asked to be seated in the gallery. He was told that there would be a one-half hour wait. Forty minutes later, the applause for his song indicated that he could proceed with the preparation. Twenty guests had ordered his favorite, a cheese souffle. (Bransford, 1979, p. 184)

Because this story violates your general restaurant script, there seems to be something wrong with it. Bransford (1979) made two points with this illustration. First, the fact that schema violations impede comprehension and memory argues for the very existence of knowledge structures like schemata. Second, suppose you subsequently learn that Jim went to a very special type of restaurant, where customers who can cook are allowed to compete for the honor of preparing their specialties for other customers. The competition involves the customer entertaining the crowd, by singing, dancing, or whatever. Now, the target passage probably makes more sense when you reread it. But Bransford contended that you must have a general restaurant schema in the first place in order to construct a modified one in which to incorporate this story.

Evidence for schema-based processing comes from another source as well. Elizabeth Loftus and her colleagues conducted a series of studies examining eyewitness memory (see Loftus, 1979, for a review). The typical procedure followed in these studies was to show subjects a videotape of a crime or automobile accident and then to ask them questions about what they remembered seeing. The type of question had significant implications for recall. In one study (Loftus & Palmer, 1974), for example, students viewed a film of an auto accident and were asked either, "About how fast were the cars going when they smashed into each other?" or "About how fast were the cars going when they hit each other?" Subjects' memory for the speed of the cars differed significantly depending on which question they were asked. Moreover, subjects asked the question with the word *smashed* reported having seen broken glass significantly more often than subjects asked the question with the word *hit*. These results suggest the possibility of a smash schema being activated and used to reconstruct memory for the auto accident event; a hit schema activates slightly different knowledge.

Although the results of Loftus' research provide support for schema theory, they should be viewed with caution when considered for their application to eyewitness testimony in a court of law. The biasing effects of questions that have been produced in the laboratory do not necessarily hold when witnesses are actively involved in a real crime or accident. Yuille and Cutshall (1986) interviewed witnesses to an actual shooting in which one person was killed and another seriously injured. Subjects showed highly accurate memory for the event over a period of 5 months, and they resisted attempts to mislead them through the wording of questions.

Solving Problems. Finally, there is evidence that schema-based processing occurs as people solve problems. Many studies have shown that experts in a domain structure their knowledge in ways different from novices (e.g., Chase & Simon, 1973a, 1973b; Chi, Glaser, & Rees, 1982; Larken et al., 1980). When attempting to solve problems, then, experts and novices build different mental models to guide their efforts.

> Our research suggests that the knowledge of novices is organized around the literal objects explicitly given in a problem statement. Experts' knowledge, on the other hand, is organized around principles and abstractions that subsume these objects. These principles are not apparent in the problem statement but derive from the knowledge of the subject matter. (Glaser, 1984, pp. 98–99)

An important aspect of mental models is that they provide a basis for reasoning. Because of their greater subject matter knowledge, experts in a domain tend to reason using specific, domain-based strategies. In a sense, their approach to problem solving is a matter of recognizing patterns that they have experienced before and matching these patterns to corresponding aspects of the problem at hand (Margolis, 1987). Novices, on the other hand, do not possess sufficiently elaborated mental models of the subject matter to permit such inferences. They are consequently forced to apply more general problem-solving strategies (such as, "Break the problem into its component parts") that lack both efficiency and power in solving specific problems.

The impact of schemata on problem solving can be quite dramatic. In a series of investigations on a logical problem known as the "four-card selection task," researchers repeatedly demonstrated that few people could solve the problem when it was presented in an abstract fashion. For instance, only 4 percent of subjects correctly determined which cards to turn over when presented with the rule, "If a label has a vowel on one side, then it has an odd number on the other" (Wason, 1968). However, when the same logical problem was put into a familiar context (e.g., "Every time I go to Manchester, I travel by train"), more than 60 percent of the subjects selected the correct cards (Wason & Shapiro, 1971).

D'Andrade (cited in Rumelhart, 1980; Rumelhart & Norman, 1981; D'Andrade, 1995) suggested that the familiar context enabled subjects to access an appropriate mental model for solving the problem. He told participants they were to imagine themselves as quality control experts in a label-making factory, and their task was to determine whether labels were incorrectly constructed. A label was correctly constructed if, when there was a vowel on one side of the label, there was an odd number on the other side. Only 13 percent of the subjects were able to appropriately apply this rule. But then D'Andrade had subjects imagine themselves as store managers inspecting store receipts with the rule, if any purchase exceeds $30, the signature of the store manager must be on the back of the receipt.

Most people have probably experienced situations such as that described in the store scenario, so that they would have developed schemata related to the checking of receipts by store managers. Checking labels at a factory, on the other hand, is probably unfamiliar to most people, which means they would have to rely upon general problem-solving logic to come up with the correct solution.

Schema Acquisition and Modification

What about learning, then? How does experience contribute to the permanent modification of schemata? Three different processes have been proposed to account for changes in existing schemata and the acquisition of new schemata due to learning. They are accretion, tuning, and restructuring (Rumelhart & Norman, 1978; Rumelhart, 1980; Vosniadou & Brewer, 1987). **Accretion** is roughly equivalent to fact learning in that *information is remembered that was instantiated within a schema as a result of text comprehension* or understanding of some event. For example, remembering from the description of mayonnaise making that a blender was used to beat the eggs is indicative of accretion. The egg-beating schema remains unchanged, but the variable for implement has been filled with blender.

When existing schemata evolve to become more consistent with experience, then **tuning** has occurred. Rumelhart and Norman (1978) suggested that this process accounts for the minor schema modifications that come with new exemplars of concepts and principles. Adding to one's egg-beating schema, the information about how long to beat for mayonnaise versus omelets is an example of tuning.

Finally, **restructuring** involves *the creation of entirely new schemata which replace or incorporate old ones.* This may occur through schema induction (Rumelhart, 1980), in which a new schema is configured from repeated consistencies of experience. Or, as Rumelhart and Norman (1981) argued, restructuring occurs most of the time through learning by analogy. In this case, a new schema is created by modeling it on an existing schema and then tuning it to fit the new situation. What typically occurs, according to Rumelhart and Norman, is that learners will try to use an existing schema to interpret the new situation, as did the child who initially applied her understanding of whipped cream to the mayonnaise problem. Areas of mismatch suggest ways in which the new schema must differ from the old, while areas that were not contradicted are carried over into the new schema.

Schema Automation and Cognitive Load

The notion of cognitive economy surfaced in Ausubel's thinking when he wrote about retention and forgetting. Recall that it is easier—more economical—to remember an inclusive concept or anchoring idea than to remember all of the details associated with it. Because schemata are conceived as packets of knowledge with slots to be filled with relevant, associated details, they are, by definition, an economical means of storing information. When schemata also become automated, processing capacity is freed so that more working memory can be devoted to tasks such as comprehending text or solving problems. This integration of concepts from information-processing theory and schema theory is the basis of cognitive load theory (Kirschner, 2002; Paas, Renkl, & Sweller, 2003; Sweller, van Merrienboer, & Paas, 1998).

Cognitive load refers to the strain that is put on working memory by the processing requirements of a learning task. When learners encounter a task for which they do not have an appropriate or automated schema, they must hold in mind all elements of the task individually and simultaneously. Think back to the examples given earlier in the chapter of readers constructing interpretations of text. If a schema to aid comprehension is not called to mind immediately, then the reader must struggle to remember each sentence in the paragraph as he or she attempts to construct a schema. However, comprehension proceeds with ease when an appropriate schema is automatically acti-

vated and brought to bear on the reading task. Similarly, in problem solving, learners who already possess an automated schema or mental model have more processing capacity in working memory to apply that schema toward solving more sophisticated problems. An important question, then, is how to facilitate the construction and automation of schemata that are useful for solving problems of interest (Sweller, van Merrienboer, & Paas, 1998).

Sweller, van Merrienboer, and Paas contend that the general strategies most learners use to solve problems when they cannot activate an appropriate schema put heavy demands on working memory. Furthermore, these strategies (such as breaking the goal into component parts) are only peripherally related to learning. The desired learning goal is for learners to construct and automate the appropriate schema or mental model that pertains to the particular class of problems to be solved. Therefore, instructional strategies should be sought that reduce extraneous cognitive load but increase germane cognitive load (Sweller, van Merrienboer, & Paas, 1998). Germane cognitive load has to do with making sure that learners engage in the cognitive processes required to construct an appropriate schema. How instruction might facilitate meaningful learning and schema construction is discussed next.

Meaningful Learning, Schema Theory, and Instruction

What do meaningful reception learning and schema theory have in common when it comes to implications for instruction? Clearly, prior knowledge plays an enormous role in both theories. What learners bring to the learning situation dictates to a large extent what they will take away from it in terms of new knowledge—concepts added to their cognitive structure or details elaborating schemata. But the content and organization of instructional materials are also important in both perspectives. Materials must be potentially meaningful to learners, organized so that connections are easily made between new information and that which is already known. To conclude this chapter, then, let us consider implications of meaningful reception learning and schema theory for activating prior knowledge, using prior knowledge in new situations, and making instructional materials meaningful.

Activating Prior Knowledge

Most learners already know something about any new topic they are asked to study, or they can make meaningful connections between what they know and what they are being asked to learn. However, possessing relevant prior knowledge is no guarantee that learners will activate and use it appropriately. It has been found in many conventional memory experiments, for example, that participants tend to view information they are asked to learn as separate and distinct from their prior knowledge (Spiro, 1977). They adopt an experiment set, which means that they approach the learning material in a rote fashion and fail to assimilate the information into related prior knowledge. Unfortunately, all too often learners tend to approach learning tasks in much the same way, regardless of whether they have prior knowledge to apply to the task. I have seen this happen in my graduate courses in which former teachers fail to use what they know about teaching to help them in learning about formal theories of learning and instruction.

In an instructional situation, then, the activation of prior knowledge should not be left to chance. To assure that meaningful learning takes place, instructors and designers can employ a variety of strategies to help learners relate their prior knowledge to new information they are to acquire. Making these connections is what Ausubel referred to as the first function of instruction, and he proposed the advance organizer as a means of accomplishing it (Ausubel, 1963a, 1968; Ausubel et al., 1978).

Advance Organizers. Advance organizers are relevant and inclusive introductory materials, provided in advance of the learning materials, that serve to "bridge the gap between what the learner already knows and what he needs to know before he can meaningfully learn the task at hand" (Ausubel et al., 1978, pp. 171–172). Ausubel et al. (1978) also stated, "organizers are presented at a higher level of abstraction, generality and inclusiveness than the new material to be learned" (p. 171). Consider why this might be so. For one thing, learners are likely to have somewhat idiosyncratic cognitive structures, and while it might be desirable to construct advance organizers for each and every learner to meet their unique needs, that is not a very practical strategy. Thus, organizers should be sufficiently general to function for a variety of learners. In addition, remember Ausubel's call for using the most inclusive and relatable concepts of a discipline to guide learning. Constructing organizers more abstract and inclusive than the learning materials is one way of doing this.

The effectiveness of advance organizers for enhancing learning and retention of verbal materials was a subject of great debate in the research literature, but in spite of contradictory findings, the concept has persisted. Some studies (e.g., Ausubel, 1960; Ausubel & Fitzgerald, 1961; Ausubel & Youssef, 1963; Kuhn & Novak, 1971; West & Fensham, 1976) confirmed the positive effects of advance organizers on learning. Others suggested that the facilitating effect might be limited to learners with low verbal or analytic ability (e.g., Ausubel & Fitzgerald, 1962). But research reviews conducted by Barnes and Clawson (1975) and Hartley and Davies (1976) pointed to even more equivocal findings.

Some of the problems cited in the research concerned methodological flaws in conducting the studies. For example, researchers may have failed to ascertain whether the organizers in their studies contained relevant concepts

that would activate existing subsumers. In the absence of analyses of the learners' cognitive structures and the concepts to be learned, Ausubel et al. (1978) argued, it is unlikely that an appropriate organizer could be constructed. Moreover, if criterion tests are either too easy or too hard, or if they are designed to measure verbatim recall, then no organizer effects should be expected.

A more serious criticism of advance organizers is that their definition is vague (Hartley & Davies, 1976). If researchers operationalize the concept of advance organizers in different ways, then it should come as no surprise that their results do not agree. Ausubel et al. (1978) countered this criticism by pointing to the volume of space in an earlier work (Ausubel, 1968) devoted to the "nature and definition of an organizer and how it affects information processing" (p. 175).

Focusing on the conditions under which advance organizers might be expected to facilitate learning, Mayer (1979) reported the results of a set of experiments he conducted to test the claims and criticisms regarding advance organizers. From his results, Mayer suggested that advance organizers should exhibit the following characteristics:

1. Have a short set of verbal or visual information,
2. Be presented prior to learning of a larger body of to-be-learned information,
3. Contain no specific content from the to-be-learned information,
4. Provide a means of generating the logical relationships among the elements in the to-be-learned information, and
5. Influence the learner's encoding process. The manner in which an organizer influences encoding may serve either of two functions: to provide a new general organization as an assimilative context that would not have normally been present or to activate a general organization from the learner's existing knowledge that would not have normally been used to assimilate the new material. (Mayer, 1979, p. 382)

Mayer (1979) went on to suggest that further research is required to determine what analogies, images, and examples in various subject matters may best serve as effective advance organizers. In order for advance organizers to work with particular students as well, they should probably be constructed by the teacher or instructional designer who has specific knowledge about what the learners already know. Mayer concluded with the following checklist for producing organizers to be used in research, suggesting that organizers that generate a yes for each question should be explored further:

1. Does the organizer allow one to generate all or some of the logical relationships in the to-be-learned material?

2. Does the organizer provide a means of relating unfamiliar material to familiar, existing knowledge?
3. Is the organizer learnable, i.e., is it easy for the particular learner to acquire and use?
4. Would the learner fail to normally use an organizing assimilative set for this material, e.g., due to stress or inexperience? (Mayer, 1979, p. 382)

Research on the advance organizer since Mayer's recommendations were published has resulted in greater emphasis on the learners' prior knowledge (e.g., Sui, 1986; Mannes & Kintsch, 1987). Learners must have necessary prior knowledge for the organizer to activate, and the organizer must draw explicit connections between old and new topics (West, Farmer, & Wolff, 1991). Synthesizing Ausubel's ideas with the results of more recent research, West et al. (1991) suggested the following procedures for constructing advance organizers:

1. Examine the new lesson or unit to discover necessary prerequisite knowledge. List.
2. Reteach if necessary.
3. Find out if students know this prerequisite material.
4. List or summarize the major general principles or ideas in the new lesson or unit (could be done first).
5. Write a paragraph (the advance organizer) emphasizing the major general principles, similarities across old and new topics. Examine examples in this text. Use them as models.
6. The main subtopics of the unit or lesson should be covered in the same sequence as they are presented in the advance organizer. (p. 125)

As can be seen in Step 5 and in the example provided in Box 4.1, West et al. have also emphasized the verbal (as opposed to visual) nature of advance organizers. Box 4.2, however, illustrates how visual material may serve effectively as an advance organizer. In this example are two diagrams I have successfully used to introduce different learning theories. These two metaphors tap what individuals know about black boxes and computers and map these onto the major concepts of behaviorism and cognitive information processing. In the former, for example, no reference is made to events or processes inside the learner. In the latter, by contrast, specific hypotheses are made to suggest that such processes are akin to what computers do with information.

Schema Signals. Like Ausubel, schema theorists recognized the importance of activating prior knowledge in learners as they engage in new learning. In reading, for example, comprehension and memory for what is read are facilitated when learners know and can access a relevant schema. This appears to be true not only for subject matter content but for the structure of the text as well. Many stories in Western culture, for example, share a common abstract structure, which includes an initial setting, adventures of a main character, and resolution of some problem that faces the main character. This story grammar or narrative schema guides both comprehension and later recall of story events (Kintsch, 1976, 1977; van Dijk & Kintsch, 1983; Rumelhart, 1975; Mandler, Johnson, & Deforest, 1976).

People may also develop schemata to guide their understanding of scientific or technical articles (Bransford, 1979; cf. Brooks & Dansereau, 1983). Most of the research articles cited in this book follow a standard schema: introduction to the problem under study, method used to conduct the investigation, results, and discussion. Other basic text structures can include simple listing, comparison/contrast, temporal sequence, cause/effect, and problem/solution (Armbruster, 1986, p. 255). Finally, different schemata may be developed for various literature genre—newspaper stories, detective fiction, etc.

In Chapter 3, the recommendation was made to signal a text's organization to readers. Not only should this help readers pay more attention to important information, but it also provides a foundation for more effective encoding. On the basis of schema theory, this recommendation must be both qualified and expanded. Instructors should alert students to the schematic structures of text materials in order to facilitate their learning, especially when the subject matter is unfamiliar. Poor readers, in particular, can comprehend more of what they read if they are taught to focus on the structure of the text (Varnhagen & Goldman, 1986).

BOX 4.1 • ***Advance Organizer for a Lesson on the Government of the United Kingdom***

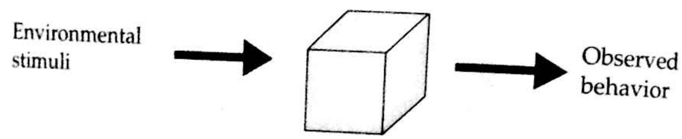
Assume that Mr. Amaya's class from the Lesson on Democracy scenario has now completed their lesson on the democratic government of the United States. As a part of that unit, they eventually discussed the three branches of government—executive, legislative, and judicial. In the following advance organizer, these branches are mentioned as a bridge to the next unit on the government of the United Kingdom.

In our unit on the U.S. government we learned that there are three branches in the federal government: the executive, the legislative and the judicial. The primary function of the legislative branch, the Congress, is the passage of laws, whereas the major task of the judicial branch is the protection of citizens' rights under the national Constitution. In this next unit on the United Kingdom, we will learn that there are also these three branches: executive, legislative, and judicial, with similar functions.

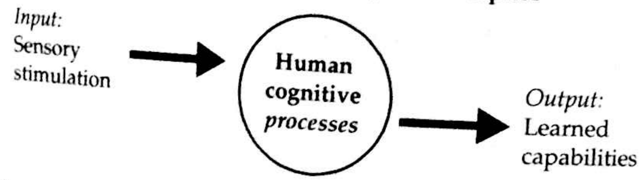
(From West, Farmer, & Wolff, 1991, p. 116.)

BOX 4.2 • *An Advance Organizer for Theories of Learning*

BEHAVIORISM: The black box metaphor



INFORMATION PROCESSING: The computer metaphor



For the most part, learners are quite familiar with the idea of a black box, in which any processes occurring are unknown. Similarly, the operation of a computer is familiar. These ideas can then serve to introduce the major concepts of behaviorism and cognitive information processing.

In addition, "Authors can help readers access the appropriate textual schemas by (a) organizing the textbook using conventional text structures—the basic text structures and/or more genre- or content-specific text structures and when these are known and appropriate, and (b) clearly signaling the text organization" (Armbruster, 1986, p. 258).

Armbruster reviewed research in which certain types of signals appeared to be effective in emphasizing certain types of text structures. For example, additive conjunctions (e.g., also, likewise) can be useful in signaling compare/contrast text structures, whereas causal conjunctions (e.g., consequently, as a result) are likely to be effective with cause/effect text structures. To help readers access or construct relevant content schemata, Armbruster (1986) concluded that current research suggests (1) the "judicious use of analogies or comparisons" (p. 261), and (2) the presentation of "well-developed concepts and thorough explanations that make explicit the important relationships among ideas" (p. 264).

Signaling the appropriate schema for word problems can also be a factor in learning arithmetic (e.g., Greeno, 1980; Sweller, Mawer, & Ward, 1983; Cooper & Sweller, 1987; Derry, Hawkes, & Tsai, 1987). Sweller (1989) asserted that a schema, if available, provides for rapid and relatively effortless problem solving. In the absence of an appropriate schema or in the case of incorrect classification of a problem, however, an inappropriate schema will be used instead.

This suggests that students should be taught and provided practice in recognizing and representing problem types. Lewis (1989), for example, taught students a diagramming method for representing compare problems in arithmetic. Fuson and Willis (1989) demonstrated that classroom teachers could successfully teach children to use schematic drawings to represent the structure of addition and subtraction problems. In both instances, the representational strategy benefited students in conceptualizing and solving a variety of problems.

An issue in problem-solving instruction as well is to manage cognitive load. That is, learners will be better able to construct and automate an appropriate schema or mental model for a particular class of problems when the instruction minimizes extraneous cognitive load but increases germane cognitive load. For example, goal-free problems focus learners on relevant problem states rather than the gap between the current state and the desired state. A goal-free problem asks learners to approach solving a problem by "calculating as many variables as you can" rather than "finding the value of *x*," which is the ultimate solution to the problem. Other strategies for managing cognitive load in problem-solving tasks include providing worked examples and partially completed problems that learners must elaborate or finish solving (Sweller, van Merrienboer, & Paas, 1998).

Finally, because social behavior and cultural knowledge can be framed in terms of schemata (e.g., Harris, Schoen, & Lee, 1986), it makes sense to consider how schema signals cue appropriate (or inappropriate) behavior in instructional situations. One of my doctoral graduates from Taiwan, for example, found his schema for multiple-choice tests to be inappropriate for taking tests in the United States. He was accustomed to selecting more than one response on multiple-choice items and did not realize, on his first test in graduate school in the United States, that only one answer would be considered correct. Needless to say, he quickly modified that schema. Given our increasingly multicultural society and the increased demands for training in international settings, it is probably wise to keep in mind the cultural schemata learners may bring to instruction.

Making Instructional Materials Meaningful

When learners encounter instruction that makes no sense to them, it becomes an impossible task to call upon prior knowledge, because there is no way to judge what knowledge will be relevant. According to Ausubel, *potentially* meaningful information must be made understandable to learners or they will approach it in a rote fashion. He claimed that the second function of instruction was to improve the discriminability among concepts. Likewise, schema theorists looked for ways to represent the content and structure of information so that learners could more easily develop appropriate schemata and mental models.

Comparative Organizers and Elaboration. Ausubel (1963) deplored the common practice of textbook writers to compartmentalize ideas or topics into separate chapters without exploring their relationships. The result, he claimed, is "incalculable cognitive strain and confusion" on the part of the learner. Students may not see, for example, how new propositions differ in substance from what they already know, causing them to dismiss the new information as unimportant. Or, they may fail to see inherent similarities or differences among concepts in the learning material itself. In this case, misconceptions are likely to result.

Consider, for example, the principles of behavior management that you studied in Chapter 2. Because there are similarities among principles that result in behavior increase (e.g., positive reinforcement, Premack principle), and among those that result in behavior decrease (e.g., punishment, extinction), these principles can be easily confused. Moreover, many learners experience confusion with negative reinforcement, which sounds like an oxymoron. The concept negative is closely associated in everyday life with aversive events, which seems to connote punishment, whereas reinforcement positively influences behavior.

To help make similar concepts more easily discriminable, Ausubel suggested the comparative organizer, which provides a means for systematically comparing and contrasting concepts. The concept tree and rational set generator depicted in Chapter 3 are examples of comparative organizers. Providing organizers to learners is one means of facilitating learning of unfamiliar, and potentially confusable, information (e.g., Ausubel & Fitzgerald, 1961; Ausubel & Youssef, 1963), but so is having learners generate them using frames such as that shown in Figure 4.7 (West et al., 1991). Mr. Amaya might find the technique especially useful in his lesson on democracy.

To enhance the stability and clarity of anchoring ideas in cognitive structure, and thus facilitate learning of information related to those ideas, Ausubel recommended starting instruction with the most general and inclusive ideas and progressively elaborating them. Ausubel called this process progressive differentiation, but Reigeluth adopted it as elaboration in his Elaboration Theory (Reigeluth, 1979, 1999; Reigeluth & Stein, 1983). According to Elaboration Theory, progressively more detail is to be elaborated in each level of instruction (from the most general, inclusive content to the most specific) until the desired level of detail is reached. The specific sequence chosen for instruction depends on which type of domain expertise is desired. Reigeluth (1999) distinguished between conceptual expertise (understanding what) and theoretical expertise (understanding why) and suggested that the general-to-detailed sequence is different for each (p. 437). In Mr. Amaya's class, for instance, it is likely that conceptual understanding is being stressed; students are learning what the different functions of government are and what differences there are among types of governments. By contrast, learning principles of cooking might involve theoretical understanding, for example, why beating eggs and oil together results in a creamy consistency. Elaboration theory provides specific guidelines for making instructional decisions about scope and sequence.

Conceptual and Pedagogical Models. According to schema theorists, the provision of conceptual and pedagogical models is a means of making instructional materials meaningful and helping learners access and refine relevant schemata and mental models.

> As designers, it is our duty to develop systems and instructional materials that aid users to develop more coherent, useable mental models. As teachers, it is our duty to develop conceptual models that will aid the learner to develop adequate and appropriate mental models. (Norman, 1982, p. 14)

Conceptual models are any of the models invented by teachers, designers, scientists, or engineers to help make some target system understandable.

Before instruction even takes place, however, teachers and designers should identify the mental models that learners bring to the instructional situation (Glaser, 1984; Gagné & Glaser, 1987). Studies in physics, for example, have shown that many learners have naive theories of physical phenomena (e.g., Lewis, Stern, & Linn, 1993; Champagne, Klopfer, & Anderson, 1980; McCloskey, Caramazza, & Green, 1980). Such naive theories may contain

	Executive	Legislative	Judicial
Description of function			
United States			
Great Britain			

FIGURE 4.7 ***A Comparative Organizer, or Frame, for a Unit on Government***

contradictory, erroneous, or unnecessary concepts, with the result that learning and problem solving become difficult and ineffective.

Tracking the development of learners' mental models through the transition from novice to expert can be a means for determining what next steps in instruction should be taken (Gagné & Glaser, 1987). In a developmental study, Carey (1985a) documented changes in children's concept of alive as they gained domain-specific knowledge about biological functions. Likewise, Siegler and co-workers (Siegler & Klahr, 1982; Siegler & Richards, 1982) found that children's reasoning about balance-scale problems was greatly influenced by experience with new information. Using a task analysis procedure to determine what theory guided children's performance, Siegler was able to match their current knowledge state with learning events that helped them move to a new level of reasoning.

Teachers' knowledge of students' problem-solving knowledge has also been associated with problem-solving achievement. Peterson, Carpenter, and Fennema (1989) concluded that more knowledgeable teachers appeared to pose problems to students, question their problem-solving processes, and listen to their solutions. These actions were related to problem-solving achievement. Less knowledgeable teachers, by contrast, tended to explain problem-solving processes to students, "thereby also doing the thinking for students" (Peterson et al., 1989, p. 568).

How can teachers ascertain the mental models of their students? There are at least four possible ways to do it: (1) Observe them; (2) ask them for an explanation; (3) ask them to make predictions; and (4) ask them to teach another student (Jih & Reeves, 1992). A mathematician who does research on math instruction, Schoenfeld (1985) often asks his students without warning to explain their reasoning on a problem or to justify the approach they are taking to solve it. Not only does this enable him to judge their mental models, but also the tactic encourages students to monitor their own mental models. "By the end of the term, I don't need to ask questions anymore. Students have gotten into the habit of analyzing where they are" (Schoenfeld, quoted in *A Mathematician's Research on Math Instruction*, 1987).

By understanding what models learners are currently using to guide their performance, teachers and designers can build upon them by specifying what Glaser (1984) called pedagogical models. These may be the same as conceptual models that have been invented to make some system understandable, or they may be a series of approximations that may be thought about and debugged in the course of instruction. diSessa (1982) referred to a kind of task analysis for identifying components of preexisting theories that can be involved in developing more sophisticated theories. Collins and Stevens (1982, 1983) offered a model of inquiry instruction that provides strategies for helping learners make predictions from and debug their current models of understanding (see Chapter 7 for more discussion of this model). For example, Anderson (cited in Collins & Stevens, 1983) assisted learners in formulating models of what geographic factors affect average temperature by getting them to form and test hypotheses about the locations and temperatures of specific places. In addition, diSessa (1982), Champagne et al. (1982), and Lewis et al. (1993) have designed computer simulations that allow physics students to explore the implications of their own theories and compare these results to the predictions of other theories.

Finally, mental models may be explicitly taught to facilitate performance (Gagné & Glaser, 1987). These conceptual models provide an important supplement to teaching strategies. "We have found that students make up their own conceptualizations anyway, and if we don't give them guidance, their models can be bizarre and difficult to overcome" (Norman, 1982, p. 108). Choosing an appropriate conceptual model to use in instruction, however, can be a difficult task. In studies of how computer-ignorant students learned to use a text editor, Norman and his colleagues faced a choice between providing an incomplete model or spending a great deal of time conveying a complete model. They found their way out of this dilemma by providing different conceptual models at different points in the instruction, each designed to elucidate a different aspect of the editor (Norman, 1982).

For pedagogical or conceptual models to effectively facilitate learning, they should meet three basic criteria: learnability, functionality, and usability (Norman, 1983). A good model is easy to learn, most likely drawing upon information that is highly familiar to learners. A good model is functional, in that it corresponds to important aspects of the target system it is designed to clarify. For example, the components making up a system might be identified as well as how these components function together to enable the system to operate (Mayer & Gallini, 1990). A good pedagogical model may not necessarily be a complete model, in the sense of representing all important aspects of the target. If this is the case, then several models may be required to fully conceptualize the desired information, and learners should be told that each one is not a perfect representation of the system being learned (Jones, 1988). Finally, a good model is easily used, given the limitations of the human information-processing system. Again, this argues for a series of incomplete models over a complete one that taxes learners' processing capabilities.

Acquisition of a mental model might not be enough for true understanding, however. "To plan, predict, invent, or otherwise make good use of a mental representation, one must not just have it, but operate with and through it" (Perkins & Unger, 1999, p. 97). For instance, the students in Mr. Amaya's class in "A Lesson on Democracy" might learn to define and explain various functions of government as well as recognize and provide pertinent examples. But can they offer and defend an interpretation of a Supreme Court ruling or elaborate connections of the case to events in their own lives?

To help learners develop the ability to understand or think flexibly about a topic, Perkins and Unger (1999) suggested what they called thought-demanding activities or *performances of understanding*. "An understanding performance both displays the learner's current understanding-so-far and, by asking the learner to solve problems, make decisions, and adapt old ideas to new situations, expands that understanding further" (p. 97). So by engaging his students in generative topics such as a Supreme Court case, Mr. Amaya may promote not only the construction of a mental model of government, but also students' ability to use that model personally and productively.

Using Prior Knowledge in New Contexts

Transfer, or the use of prior knowledge in new contexts, is routinely taken to be one of the most important instructional goals. Teachers want students to transfer the arithmetic skills they learn in school to everyday activities such as balancing a checkbook and judging good buys at the supermarket. Or, they hope learners will use their knowledge of science to make wise choices about the use of energy and other environmental resources. Bank executives want manager-trainees to transfer to the job the knowledge and skills they acquire in training programs. And fighter pilots must be able to solve problems in the air similar to those they have encountered in simulators or printed instructional manuals.

Both Ausubel's meaningful reception learning and schema theory can be conceived as theories about transfer, because they are concerned with the effect that prior knowledge has on the learning of new information. Schema theory is more comprehensive than meaningful reception learning in being able to account for how learners bring to bear what they know on solving problems. But neither theory is focused particularly on how people learn when to use their knowledge. Although transfer may be a matter of invoking a relevant schema, determining when a schema is relevant turns out to be no easy task.

Recall the study by D'Andrade in which subjects were given the rule, "If a label has a vowel on one side, it should have an even number on the other." They performed poorly unless problems were couched in the context of a familiar schema (i.e., store receipts in amounts greater than $30 must have the manager's signature on the reverse side). In a similar study, individuals trained in the logic of the conditional were expected to perform well on problems involving this rule (Cheng et al., 1986). Results indicated, however, that knowledge of logic did not transfer. Like D'Andrade's subjects, the individuals in the study of Cheng et al. (1986) performed much better when the rule was phrased in more familiar terms (e.g., "if a person is drinking alcohol, then he must be over 21" or "If a person enters this country, she must

have had a cholera shot"). Cheng et al. (1986) explained their findings in terms of a permission schema, which has a limited range of transfer.

Price and Driscoll (1997) concluded, however, that schema theory may be more limited in its ability to account for such results than Cheng et al. (1986) believed. They replicated D'Andrade's study with two modifications. Some subjects had practice in solving the problem in the familiar scenario before encountering the same problem in an unfamiliar scenario, and some subjects were provided feedback after the first problem to help them abstract the problem schema. Although feedback eliminated one of the errors subjects commonly make, neither intervention improved problem-solving performance.

Results such as these contribute to the ongoing debate as to whether transfer is highly limited in scope or whether it is broad and ranges across diverse domains. Whichever is the case, it should not be left to chance (Price & Driscoll, 1997). Rather, it is probably worth the effort of a teacher or designer to consider just what sort of transfer is desired and take steps to include instructional conditions that will effectively support it. In Chapter 5, situated cognition theory is explored as a promising approach to facilitating knowledge transfer.

Conclusion

The question of how knowledge is acquired, represented, accessed, and used is a complex one, for which there are no easy answers. This chapter has presented several contemporary approaches to knowledge representation for learning, thinking, and problem solving that provide insights beyond those of cognitive information-processing theory. But they, along with this chapter, have only scratched the surface.

> The solution to the riddle of Holmes and Watson is that they must have walked along the veranda from right to left. After they broke into the house round the corner from one end of the veranda, they passed through various rooms and along a corridor, and then they turned right into Milverton's study and saw a door that communicated with the veranda. (Johnson-Laird, 1983, p. 166)

Schema and Meaningful Reception Learning in "Kermit and the Keyboard"

Ausubel had little to say about learning of motor skills, so his theory does not account well for aspects of Kermit's learning that involve actually playing the keys to produce a sound. However, the conceptual knowledge about music that goes along with the ability to play is subject to analysis from the

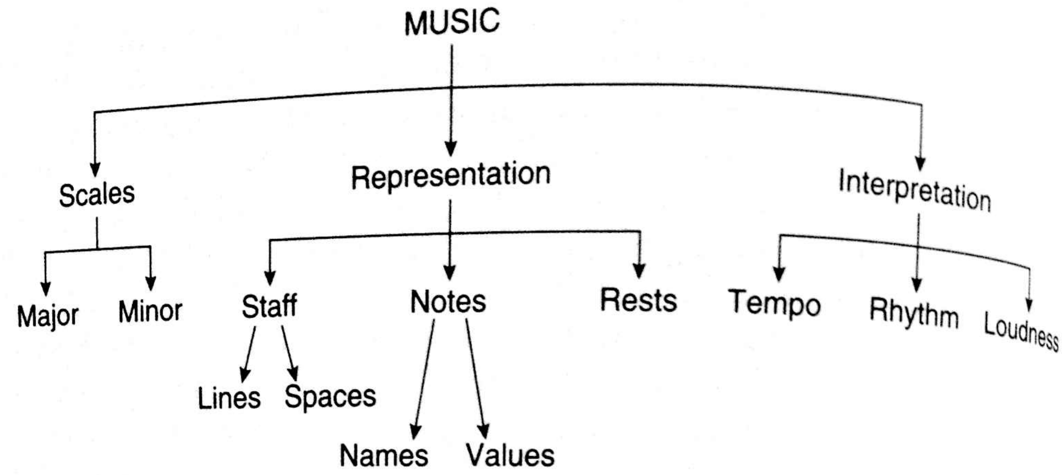


FIGURE 4.8

perspective of Ausubel's theory. For instance, Kermit might have developed a cognitive structure like the one in Figure 4.8 (please keep in mind that this is not my area of expertise!).

As he learns particular notes, particular rhythms, and so on, Kermit's cognitive structure would become progressively more elaborated. How might we account for the mistake that Kermit makes in playing "House of the Rising Sun"? Let's assume that under the anchoring idea "rhythm," Kermit subsumes different types of the 4/4 time signature, such as ballad, march, and beguine. These also correspond to different backgrounds on the keyboard, and it is only when Kermit selects beguine that he plays one note too long. That version of the song is now derivatively subsumed as an example of beguine, whereas the correct version of the song is subsumed under ballad.

From the standpoint of schema theory, Kermit may have developed a schema for "symphony" in which was instantiated for "music played in concert" the detail of "a small set of music pieces repeated over time." His schemas for types of music such as ballads and marches would also include the tempos and styles in which they are played (at least the schemas would come to include these attributes as Kermit learned them and instantiated their unique characteristics; both ballad and march would be instantiated as examples of the larger schema related to time signature). Because of this, the background he selected to play with "House of the Rising Sun" could activate a schema that might cause him to misinterpret how long the offending note should be played. Thus, he expected to see something different than what was actually written, and this expectation guided his action. Because the result still sounded fine, there was nothing to correct Kermit's mistake.

Theory Matrix

Theory	Meaningful Reception Learning	Schema Theory
Prominent Theorists	D. P. Ausubel; R. E. Mayer	D. A. Norman; D. E. Rumelhart; J. Sweller; J. van Merrienboer
Learning Outcome(s)	Organized conceptual knowledge that involves understanding	Organized conceptual knowledge and mental models that can be used to interpret events and solve problems
Role of the Learner	Make connections between prior knowledge and to-be-learned information that results in an elaborated cognitive structure	Construct schemata and mental models Use, modify, and automate schemata in solving problems
Role of the Instructor	Make materials meaningful to the learner Activate learners' prior knowledge, and organize instruction to help them make meaningful connections to what they already know	Activate learners' existing schemata Help learners develop and refine appropriate mental models, manage cognitive load. Use thought-demanding activities to facilitate understanding
Inputs or Preconditions to Learning	Potentially meaningful materials, an orientation toward meaningful (as opposed to rote) learning, relevant prior knowledge	Preexisting schemata that can be modified or reconstructed by analogy to account for new knowledge Materials and problems that do not overload working memory.
Process of Learning	Incorporating new information into cognitive structure by attaching it to anchoring ideas through processes of subsumption, superordinate and combinatorial learning	Accretion, tuning, and restructuring of schemata Automation of schemata