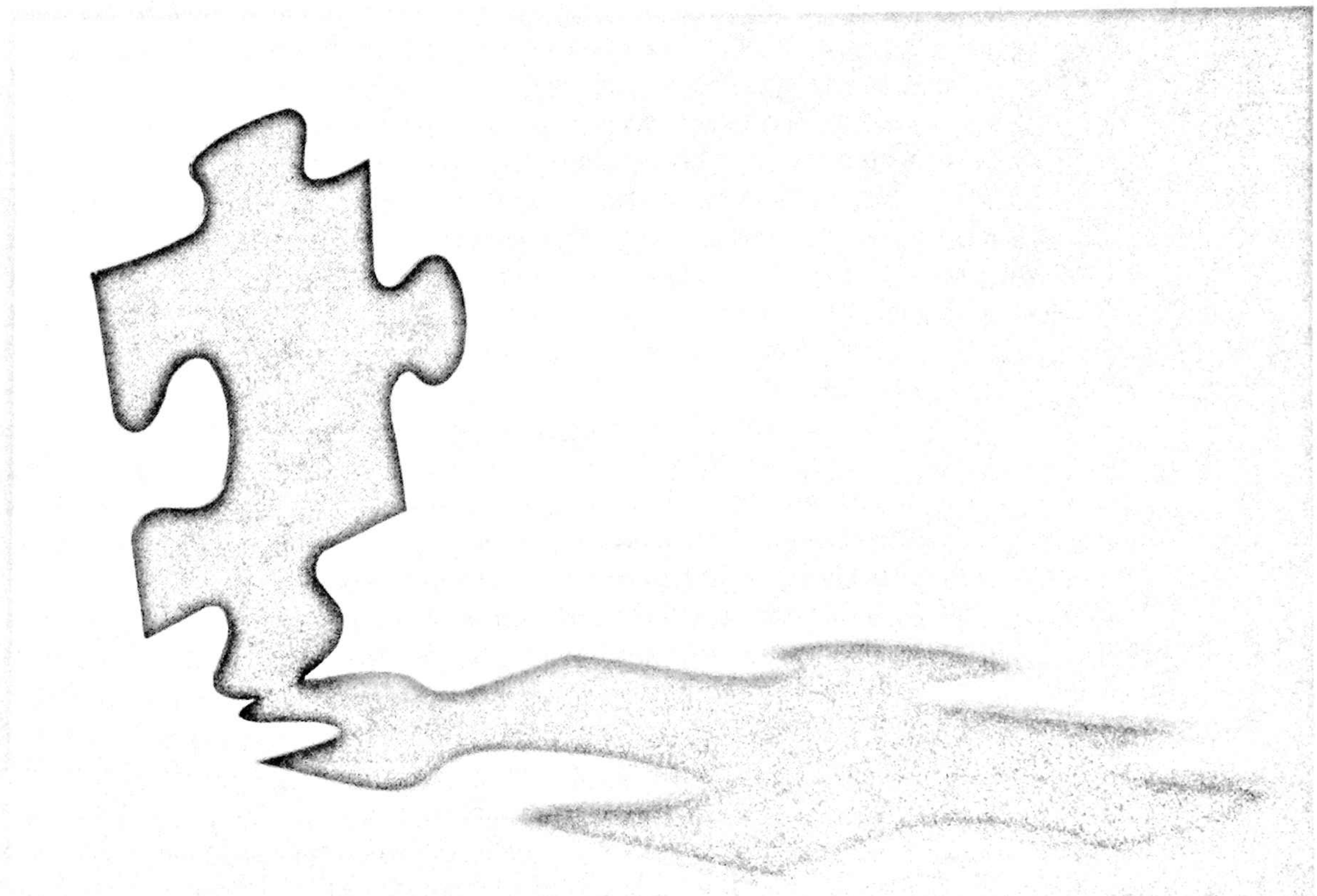
11

Teaching by Fostering Learning Strategies

Chapter Outline

The process of meaningful learning depends both on the material that is presented (i.e., the teaching side of the process) and on the way the material is processed by the learner (i.e., the learning side of the process). Thus, two ways of fostering the process of meaningful learning are improving the way that material is presented (i.e., instructional methods) and improving the way that students process information (i.e., learning and thinking strategies). Previous chapters focused on instructional methods as the key to promoting student learning. This chapter takes a more direct approach by exploring whether students can learn to be more effective learners. In short, we seek to help learners build learning strategies that allow them to learn in ways that promote transfer. In this chapter, you learn about three types of learning strategies—mnemonic strategies for memorizing material, structure strategies for helping students organize material, and generative strategies for helping students integrate new material with their existing knowledge.



How to Turn a Passive Learning Task into an Active Learning Task

Reading a textbook lesson or listening to a lecture seems to be a passive task. Yet successful students turn this seemingly passive task into an active one in which they try to make sense of the presented material. For example, please read the lightning passage in Figure 11–1, using any strategies that will help you learn it. In an attempt to take an active approach, you might read every word aloud or even copy the entire passage into a notebook. What's wrong with either of these approaches? In spite of your being prompted to be behaviorally active (i.e., talking or writing), you are not being cognitively active (i.e., you are not trying to make sense of the material). Learning strategies are intended to help learners become cognitively active learners.

A learning strategy refers to cognitive processing performed by a learner at the time of learning that is intended to improve learning. This definition has three main parts: (1) a learning strategy involves intentional cognitive processing by the learner; (2) a learning strategy occurs at the time of learning; and (3) a learning strategy is intended to improve learning. This definition is broad enough to include techniques ranging from strategies for memorizing facts in a lesson, to strategies for outlining a lesson, to strategies for summarizing a lesson.

Learning strategies may focus mainly on helping you recall specific facts, on helping you organize the material into a coherent structure, or on helping you integrate the material with your prior knowledge and experience. If you focus on learning strategies for memorizing, you might choose a few key ideas and try to commit them to memory. For example, to remember that negative charges fall to the bottom of the cloud and positive charges rise to the top, you might imagine the cloud as a wrestling ring in which a big, muscular figure with a plus sign on his chest is stepping on a defeated wrestler with a minus sign on his chest. In this way, you can remember that the pluses are above the minuses in the cloud.

If you focus on learning strategies for organizing, you might create a flowchart showing the main steps in lightning formation, such as "cool, moist air moves over warm surface" followed by "air becomes heated and rises" followed by "air forms a cloud," and so on. In this way, you select relevant information and organize it into a structure (i.e., a cause-and-effect chain).

If you focus on learning strategies for integrating, you might ask yourself why questions, such as "Why do negative charges in the cloud move toward the ground?" In trying to answer, you might recall that negatives and positives attract, so the negative charges in the cloud are attracted to the positive charges on the earth's surface. In this way you actively relate the presented material to your existing knowledge.

What does a skilled learner know about how to process passages or lectures that a less-skilled learner does not know? A less-skilled learner might view a passage or lecture as a list of unrelated facts in which the goal is to carefully study every word. A more-skilled learner may view a passage or a lecture as an organized body of knowledge that makes sense. Such a reader knows how to select relevant material, how to organize the material into a coherent structure, and how to integrate the material with existing knowledge. These kinds of cognitive processes are primed by *learning strategies*. Learning strategies may be crucial for a student's success in school. Although some students acquire these skills without explicit training, other students do not master even the most basic learning

FIGURE 11–1
A passage about lightning

Lightning can be defined as the discharge of electricity resulting from the difference in electrical charges between the cloud and the ground.

When the surface of the earth is warm, moist air near the earth's surface becomes heated and rises rapidly, producing an updraft. As the air in these updrafts cools, water vapor condenses into water droplets and forms a cloud. The cloud's top extends above the freezing level. At this altitude, the air temperature is well below freezing, so the upper portion of the cloud is composed of tiny ice crystals.

Eventually, the water droplets and ice crystals in the cloud become too large to be suspended by updrafts. As raindrops and ice crystals fall through the cloud, they drag some of the air from in the cloud downward, producing downdrafts. The rising and falling air currents within the cloud may cause hailstones to form. When downdrafts strike the ground, they spread out in all directions, producing gusts of cool wind people feel just before the start of the rain.

Within the cloud, the moving air causes electrical charges to build, although scientists do not fully understand how it occurs. Most believe that the charge results from the collision of the cloud's light, rising water droplets and tiny pieces of ice against hail and other heavier, falling particles. The negatively charged particles fall to the bottom of the cloud, and most of the positively charged particles rise to the top.

The first stroke of a cloud-to-ground lightning flash is started by a stepped leader. Many scientists believe that it is triggered by a spark between the areas of positive and negative charges within the cloud. A stepped leader moves downward in a series of steps, each of which is about 50 yards long, and lasts for about 1 millionth of a second. It pauses between steps for about 50 millionths of a second. As the stepped leader nears the ground, positively charged upward-moving leaders travel up from such objects as trees and buildings, to meet the negative charges. Usually, the upward moving leader from the tallest object is the first to meet the stepped leader and complete a path between the cloud and earth. The two leaders meet generally about 165 feet above the ground. Negatively charged particles then rush from the cloud to the ground along the path created by the leaders. It is not very bright and usually has many branches.

As the stepped leader nears the ground, it induces an opposite charge, so positively charged particles from the ground rush upward along the same path. This upward motion of the current is the return stroke and it reaches the cloud in about 70 microseconds. The return stroke produces the bright light that people notice in a flash of lightning, but the current moves so quickly that its upward motion cannot be perceived. The lightning flash usually consists of an electrical potential of hundreds of millions of volts. The air along the lightning channel is heated briefly to a very high temperature. Such intense heating causes the air to expand explosively, producing a sound wave we call thunder.

strategies. In spite of this problem, until quite recently, not much emphasis was placed on teaching students how to learn. This chapter deals with the teaching of learning strategies.

A growing number of psychologists and educators argue for the importance of teaching students how to learn (i.e., of including learning strategies as part of the curriculum). For example, Norman (1980) observed:

> It is strange that we expect students to learn yet seldom teach them anything about learning. . . . We sometimes require students to remember a considerable body of material, yet seldom teach them the art of memory. It is time that we make up for this lack, time that we developed the applied disciplines of learning . . . and memory. We need to develop the general principles of how to learn, how to remember . . . and then develop applied courses, and then establish the place of these methods in an academic curriculum (p. 97).

Norman referred to an emerging discipline of *cognitive engineering*—the development of ways to control our own cognitive processes.

Can students be taught to be more efficient processors of information? Are there learning strategies that can be taught to students that will improve their understanding of material such as in Figure 11–1? If you had investigated these questions a few decades ago, you would have found that teachers rarely taught learning skills in elementary classrooms (Durkin, 1979). More recently, however, "we now have a large number of studies that demonstrate that cognitive strategies can successfully improve instruction in a number of domains as reflected by improved student scores" (Pressley & Woloshyn, 1995, p. iv). In short, the teaching of cognitive strategies represents "the most important instructional advance of the past 15 years" (p. iii).

The issue of learning strategies is explored in this chapter. In particular, this chapter investigates three techniques for improving verbal learning: (1) mnemonic strategies for increasing memory of relevant material, (2) structure strategies for organizing material, and (3) generative strategies for integrating new material with existing knowledge.

Mnemonic Strategies

WHAT ARE MNEMONIC STRATEGIES?

To learn the lightning explanation in Figure 11–1, you need to remember certain basic facts about key terms, such as "stepped leader is the negative charge that moves from the cloud to the ground" and "freezing level is the level that the top of the cloud is above." Part of school learning involves memorizing facts. Facts are simple verbal propositions that link one element with another, or with an attribute. For example, students may be asked to memorize the states and their capitals, such as "the capital of California is Sacramento," or mathematical definitions, such as "a square is a polygon that has four equal sides and four equal angles." Some facts can be viewed as paired associates in which the first element in a pair (such as "the capital of California") is associated with the second element in a pair (i.e., "Sacramento").

Mnemonic strategies are techniques that help students memorize material such as facts. Memorization means that you are able to remember and use the material without conscious mental effort. For example, when I ask, "What is the capital of California," you can say

"Sacramento" without effort. How do mnemonic strategies promote transfer? On the surface, it might seem contradictory to say that memorization is a good way to promote transfer. However, mnemonic strategies promote transfer in two ways. First, when you have memorized basic facts, it takes minimal mental effort to use them in higher-order thinking. For example, if you already know the definitions of many words, it is easier to comprehend the theme of a passage than if you have to try to make sense of each new word. Second, when the to-be-learned material seems senseless, mnemonic strategies offer a means of creating some degree of meaningfulness, usually by embedding the material in a more concrete context.

THEORY: HOW DO MNEMONIC STRATEGIES WORK?

Mnemonic strategies involve time-tested activities that help the learner remember material. In a historical review of mnemonics, Yates (1966) noted that Simonides developed an imagery-based mnemonic system 2,500 years ago. Since that time, most practitioners of mnemonics have attempted to develop useful techniques rather than to provide a theory of human memory. In contrast, Paivio (1971) argued that mnemonic strategies may work for a number of reasons:

Dual coding: Many memory strategies involve using imagery as well as verbal representations. This approach provides two distinct codings of the same material; hence, there are more ways to find the information in memory.

Organization: Many memory strategies provide a coherent context or organization into which new information can be fit. The organization serves to hold the information together rather than as many separate bits.

Association: Many memory strategies involve forming strong associations between elements. Stronger associations allow for superior remembering.

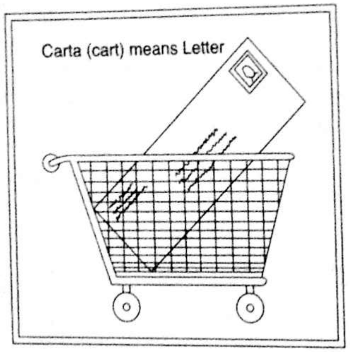
As you can see, mnemonic methods prompt the learner to become more cognitively active by forming images or making mental connections, although a precise theory is still forthcoming. Thus, the present section presents a typical mnemonic strategy—the keyword method—aimed at getting facts firmly into memory.

RESEARCH: DO MNEMONIC STRATEGIES WORK?

Keyword Method The modern impetus for educational applications of mnemonic techniques comes from research on the keyword method for teaching foreign language vocabulary by Atkinson and Raugh (Atkinson, 1975; Atkinson & Raugh, 1975; Raugh & Atkinson, 1975). For example, in memorizing Spanish-to-English vocabulary such as, "carta" which means (postal) "letter," the keyword method involves two stages:

1. *Acoustic link.* You change the foreign language word into an easily pronounced English keyword that sounds like part of the foreign word. For example, you could convert "carta" into "cart."
2. *Imagery link.* You form an interacting image to combine the keyword and the corresponding English word. For example, you could imagine a large postal letter in a shopping cart, such as shown in Figure 11–2. It is not necessary that the image be unusual or bizarre.

URE 11–2 An ge that links the word "cart" "letter"



Source: Reprinted from Journal of Experimental Child Psychology, 26, *M. Pressley & J. R. Levin, Developmental constraints associated with children's use of the keyword method of foreign language vocabulary learning, pp. 359–372 (art created by M. Pressley), Copyright © 1978, with permission from Elsevier.*

In a typical experiment, Raugh and Atkinson (1975) asked college students to learn 60 Spanish-to-English vocabulary pairs in 15 minutes. Examples (with keywords in parentheses) include charco (charcoal)/puddle, gusano (goose)/worm, nabo (knob)/turnip, and trigo (tree)/wheat. Experimental students were given pretraining in use of the keyword method. During learning, the keywords were provided but the subjects had to generate their own images. Control students were given the same 60 vocabulary pairs, including keywords, for the same amount of time as the experimental group. These students were instructed to rehearse the pairs so they could perform well on the test. On a subsequent test, the experimenter read the Spanish words and asked the students to write the corresponding English word. The experimental group scored 88% correct on this test, compared to 28% for the control group. In another study involving Russian vocabulary, students who used the keyword method recalled 72%, compared to 46% for the control group (Atkinson & Raugh, 1975).

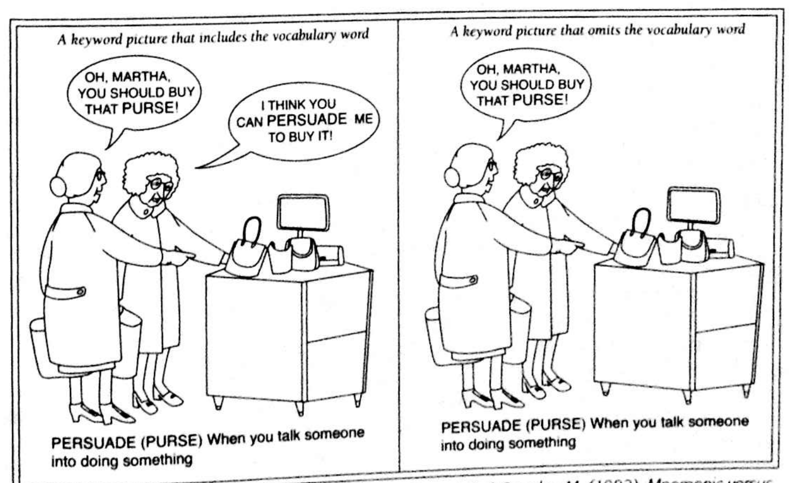
Based on these results, it appears that the keyword method is far more effective than other methods, such as rehearsal and recitation. In teaching college students, Raugh and Atkinson (1975) suggested that the keyword method works best when the instructor provides the keyword (i.e., a short English word that sounds like part of the foreign language word) and when the learner is allowed to form his or her own image. However, Pressley and colleagues (Pressley, 1977; Pressley & Dennis-Rounds, 1980; Pressley & Levin, 1978) found that younger children experience difficulty in spontaneously generating useful images even when they are trained to do so. Pressley and Dennis-Rounds found evidence that children as old as 12 do not spontaneously use the keyword method even after they received training in how to use it. Thus, Levin (1981) and Pressley (1977) suggest that when the students are children, the keyword method should be adapted to provide both keywords and pictures.

As an example, consider how the keyword method could be adapted to help elementary school children learn English vocabulary. In a typical study (Levin, McCormick, Miller, Berry, & Pressley, 1982), fourth graders learned the definitions of 12 verbs, such as "celebrate," "gesture," "glisten," "harvest," "hesitate," "intend," "introduce," "object," "orbit," "persuade," "relate," and "resolve." Students in the experimental group learned a keyword for each vocabulary word; the keyword was a familiar word that sounded like a salient part of the vocabulary word, such as the keyword "purse" for the vocabulary word "persuade." Then the experimental students were given pictures that showed the keyword interacting with the definition of the vocabulary word, such as a woman being persuaded to buy a purse; at the bottom of the picture was the vocabulary word's formal definition. The left panel of Figure 11–3 provides an example picture. The control students were given training in recognizing the words and were given sentences such as, "The woman's friend was trying to persuade her to buy a pocketbook." They also were given the formal definition for each word in the same words as in the experimental group. Control students were given the same amount of time to learn the definitions and were told to use their own best method. On a subsequent test, the keyword students recalled 83% of the definitions, compared to 55% for the control students.

These results suggest that recall is aided by giving children explicit pictures that connect the keyword and its definition. However, Levin et al. (1982) also found that pictures that do not explicitly connect the vocabulary word to the keyword, such as in the right panel of Figure 11–3, do not improve learning. Similarly, in another study (Levin et al., 1982), students who learned vocabulary with pictures that gave both the keyword and the vocabulary word (e.g., left panel of Figure 11–4) recalled almost twice as many definitions as students who learned with pictures that failed to give the keyword (e.g., right panel of Figure 11–4). These results suggest that pictures or keywords alone are not enough to enhance memory in elementary school children; successful keyword techniques in children seem to require pictures showing both the keyword and the vocabulary word.

In another series of experiments, Pressley, Levin, and McCormick (1980) used a modified version of the keyword method to teach Spanish-to-English vocabulary to second- and

FIGURE 11–3 Keyword pictures for learning the definition of persuade



Source: From Levin, J. R., McCormick, C. B., Miller, G. E., Berry, J. K., & Pressley, M. (1982). Mnemonic versus nonmnemonic vocabulary learning strategies for children. American Educational Research Journal, 19, *121–136. Copyright © 1982 by American Educational Research Association.*

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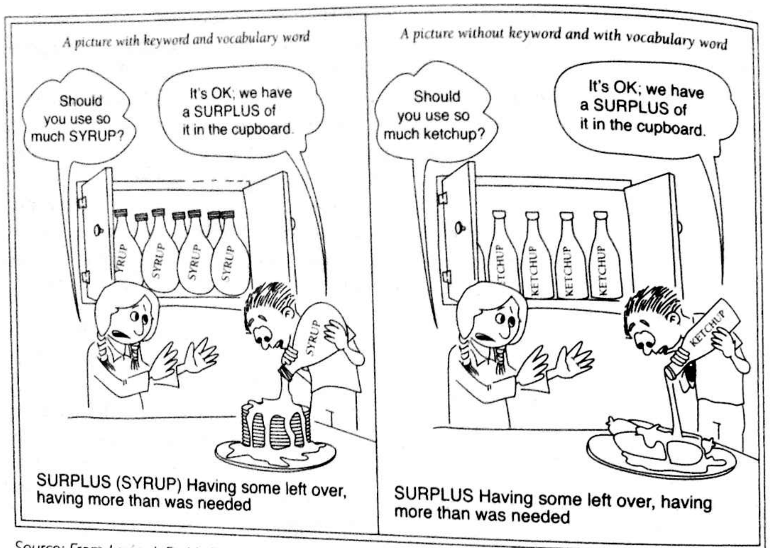

Source: From Levin, J. R., McCormick, C. B., Miller, G. E., Berry, J. K., & Pressley, M. (1982). Mnemonic versus nonmnemonic vocabulary learning strategies for children. American Educational Research Journal, *19, 121–136. Copyright © 1982 by American Educational Research Association.*

fifth-graders. All subjects learned the keyword for each Spanish word, but unlike previous studies, no pictures were used for the experimental group. Instead, the experimental group was instructed as follows: "The Spanish word __________ sounds like __________ (keyword) and means __________. Make up a sentence in your head about a (keyword) and a (translation) doing something together in order to remember the meaning of (Spanish word)." The control group was told, "The Spanish word __________ means __________. Try hard to remember that the Spanish word means __________." Although all subjects learned the same keyword and spent the same time learning, the experimental group remembered more than twice as many Spanish-to-English vocabulary items as the control group—72% correct versus 27% correct, respectively.

Does using the keyword method to memorize vocabulary words affect higher-level learning as well? To examine this question, Jones, Levin, Levin, and Beitzel (2000) taught some elementary school students how to apply the keyword method to learning the definitions of 16 unfamiliar words that were subsequently used in a story. For example, for the definition "carlin—old woman," students might recode "carlin" as "car" and generate an imageful sentence such as "The old woman was driving a car." Other students were instructed to use a more conventional strategy of forming a sentence using the word, such as "The carlin had great difficulty climbing the stairs." As a retention test, students were asked to write the definitions for all the words they could remember. As a transfer test, students were asked to read a story containing the words and then to answer comprehension questions that did not directly involve any of the vocabulary words. Consistent with previous research (Levin, Levin, Glasman, & Nordwall, 1992), students who received instruction in how to use the

keyword method correctly remembered 91% of the word definitions, compared to 51% for students who were taught to use the conventional strategy. Importantly, students who were taught how to use the keyword method generated correct answers on 68% of the comprehension items that were unrelated to the vocabulary words, compared to 51% for the students who were taught to use the conventional strategy. These results show that memorizing the meaning of vocabulary words helps promote understanding of a passage that uses the words—even those parts of the passage that do not involve the vocabulary words. In short, it appears that students who successfully use the keyword method are also more likely to show evidence of understanding, as measured by transfer tests.

In a review of research on mnemonic strategies, Pressley and Woloshyn (1995) concluded, "We are optimistic that the keyword method will prove to be a potent strategy that can be taught quickly and efficiently" (p. 67). More recently, researchers have successfully used mnemonic techniques to improve student's memory for the English translations of Chinese characters (Kuo & Hooper, 2004), student's memory for the names of fish corresponding to pictures of fish (Carney & Levin, 2003), and students' memory for the facts associated with each theorist's name in a text passage on the psychology of intelligence (Rummel, Levin, & Woodward, 2003).

Elaboration Strategies The keyword method is just one example of a successful mnemonic strategy for memorizing facts. There are many other mnemonic strategies that have educational potential for helping students learn facts or lists (Paivio, 1971; Pressley & Woloshyn, 1995). For example, an important extension of mnemonic techniques involves helping students remember procedures by helping them create a story.

Suppose you visit an eighth-grade math class and find some students who have great difficulty in solving computation problems involving addition, subtraction, multiplication, and division. For example, most are unable to solve a basic subtraction problem such as

$$\begin{array}{r} 75.6 \\ \underline{-43.0} \end{array}$$

To help these low-performing students learn the subtraction procedure, we create a story in which the numbers are warriors and the operators are actions. For example, for the subtraction problem given above, the number on top (consisting of attacking warriors) is fighting the number on the bottom (consisting of defending warriors). Each digit indicates the strength of the warriors, so the warriors with 7 are stronger than the warriors with 4. The decimal point indicates that the warriors to the right are unranked and those to left are ranked. In order to fight, the warriors line up properly so the ranked warriors on one side are lined up against ranked warriors on the other side, and unranked warriors on one side are lined up against unranked warriors on the other side. The top group (consisting of 75.6) represents attackers and the bottom group (consisting of 43.0) represents defenders. You can recognize the defenders because they have their sword drawn, as indicated by the subtraction sign (−). Imagine that the attackers are trying to get past the defenders so they can get past the gate, as indicated by the line under the bottom number. As the attackers battle their way past the defenders they are weakened. If the attacker's strength is less than the defender's strength in any position, they must call in help (to increase their strength by 10) from their fellow warriors to the left (which give up 1 in strength). To use this mnemonic you can see that for unranked warriors there is no defense against the 6 unranked attackers so 6 of them make it past the gate; in the middle position, 3 defenders cancel out 3 of the 5 attackers, leaving 2 to get past the gate; and in the leftmost position, 4 defenders cancel out 4 of the 7 attackers, leaving 3 attackers to get past the gate. Below the gate, the answer is 32.6.

Does using this story help students remember the subtraction procedure? Manalo, Bunnell, and Stillman (2000) taught this mnemonic story (as well as mnemonics for addition, multiplication, and division) to some low-performing eighth-grade math students in New Zealand and demonstrated how to use it. The results showed a strong effect: Students who received training in the mnemonic story showed an improvement from 16% on a pretest to 84% correct on a posttest, whereas students who did not receive the mnemonic training scored 20% correct on a pretest and 17% on a posttest. Similar effects were found for addition, multiplication, and division. The researchers conclude: "process mnemonics can be used effectively to teach computational skills to students with mathematics learning disabilities" (p. 152). We can call this a type of *elaboration strategy* because the students must elaborate on the procedure they are trying to learn. Overall, this research represents a promising extension of mnemonic techniques to learning of procedures.

IMPLICATIONS OF MNEMONIC STRATEGIES

Suppose that students are required to learn foreign language vocabulary or definitions of English words as part of the regular instructional program. Some students will have no difficulty with this task and do not need special training in mnemonic strategies. However, some students will have great difficulty, and for them, training in mnemonics holds some promise. For example, this section showed that learning of paired associates can be improved through explicit instruction in the keyword method. Mnemonic strategies may positively affect transfer because they allow the learner speedy access to relevant knowledge that is needed on transfer tests.

The work of Pressley and Levin showed that mnemonic strategies need to be adapted to the needs of the student. For example, in learning the keyword method, some students may not be able to form their own images and may need teacher-provided images. These students can benefit from practice in using teacher-imposed images to remember paired associates. Others may be able to form images but may need to be told to do so by the teacher. These students can benefit from practice in forming useful images for paired associates. Finally, for students who are proficient at using the keyword method but unsure about when to use it, practice is needed in recognizing appropriate learning tasks.

Structure Strategies

WHAT ARE STRUCTURE STRATEGIES?

Let's return to the lightning passage in Figure 11–1. Suppose we want to help the reader mentally organize this information. We might ask the reader to create an outline or a flowchart showing the steps in the cause-and-effect chain. Structure strategies such as writing an outline or drawing a graphic enable the learner to impose organization on the material. This section explores the idea that students can learn strategies for how to organize verbal material. In particular, it focuses on mapping and outlining methods.

THEORY: HOW DO STRUCTURE STRATEGIES WORK?

Structure strategies prompt active learning by encouraging learners to mentally select relevant pieces of information and relate them to one another within a structure. In a previous chapter, we referred to this process as building internal connections. However, students may need training in how to identify key ideas and connect them into a coherent organization.

Graesser (1981) distinguished between narrative prose, such as stories, and expository prose, such as explanations of events or objects. This distinction is important because ample evidence indicates that students are better able to organize and remember narrative passages than expository passages that are equally complex (Graesser, Hauft-Smith, Cohen, & Pyles, 1980). Apparently, people have had a great deal of experience with stories and therefore have developed expectations about how events and states in stories can be organized.

In contrast, most people lack extensive experience in reading expository prose and therefore are less likely to possess strategies for organizing it. Meyer, Brandt, and Bluth (1980) argued that readers may use a default strategy of organizing expository prose as a list of facts. One implication of this lack of experience is that students could profit from explicit training concerning expository prose structures. Successful training would help students build internal connections among the central ideas in a passage. The outcome of such learning would be manifested in increased memory for the central ideas in a passage (rather than details) and in superior performance of problem-solving tests involving inference.

RESEARCH: DO STRUCTURE STRATEGIES WORK?

Learning to outline textbook material or lecture material is widely recognized in the folk wisdom of our culture as an important study skill. What evidence exists that structure strategies such as outlining techniques improve learning? This section explores two effective techniques for teaching students how to structure text material: mapping (in which students create graphic outlines) and outlining (in which students create written outlines).

Mapping Strategies Suppose that you were asked to read a passage about wounds from a nursing textbook. To help you organize the material you could try to construct an outline. To do this, you must first identify and summarize each of the ideas in the text (i.e., what you will write on each line of the outline) and then you must determine how they are related to one another (i.e., which ideas are subordinate to which other ideas).

Dansereau and colleagues (Chmielewski & Dansereau, 1998; Dansereau, 1978; Dansereau et al., 1979; Dansereau & Newbern, 1997; Holley, Dansereau, McDonald, Garland, & Collins, 1979) have developed a technique called *knowledge mapping* in which the student identifies ideas and relations among them. In a typical outline, the only kind of relation is subordination (i.e., one idea is subordinate to another). To help the student better understand the relationships among ideas in a passage, Dansereau and colleagues identified several kinds of links. As summarized in Figure 11–5, the relation between one idea and another can be any of the following: part of, type of, leads to, analogous to, characteristic of, or evidence for.

FIGURE 11–5 Six types of links for expository prose

	Hierarchy Structures	
Part (of) Link hand ↑ p ↓ finger	The content in a lower node is part of the object, process, idea, or concept contained in a higher node.	*Keywords* is part of is a segment of is a portion of
Type (of)/Example (of) Link school ↑ t ↓ private	The content in a lower node is a member or example of the class or category of processes, ideas, concepts, or objects contained in a higher node.	*Keywords* is a type of is in the category is an example of is a kind of
	Chain Structures	
Leads to Link practice ↑ l ↓ perfection	The object, process, idea, or concept in one node leads to or results in the object, process, idea, or concept in another node.	*Keywords* leads to results in causes is a tool of produces
	Cluster Structures	
Analogy Link College ↓ a ↓ factory	The object, idea, process, or concept in one node is analogous to, similar to, corresponds to, or is like the object, idea, process, or concept in another node	*Keywords* is similar to is analogous to is like corresponds to
Characteristic Link sky ↓ c ↓ blue	The object, idea, process, or concept in one node is a trait, aspect, quality,feature, attribute, detail, or characteristic of the object, idea, process, or concept in another node.	*Keywords* has is characterized by feature is property is trait is aspect is attribute is
Evidence Link broken arm ↓ e ↓ X-ray	The object, idea, process, or concept in one node provides evidence, facts, data, support, proof, documentation, confirmation for the object, idea, process, or concept in another node.	*Keywords* indicates illustrated by demonstrated by supports documents is proof of confirms

Source: Reprinted from C. D. Holley, D. F. Dansereau, B. A. McDonald, J. C. Garland, & K. W. Collins, Evaluation of a hierarchical mapping technique as an aid to prose processing, Contemporary Educational Psychology, *4, pp. 227–237, Copyright © 1979, with permission from Elsevier.*

FIGURE 11–6 A network of a chapter from a nursing textbook

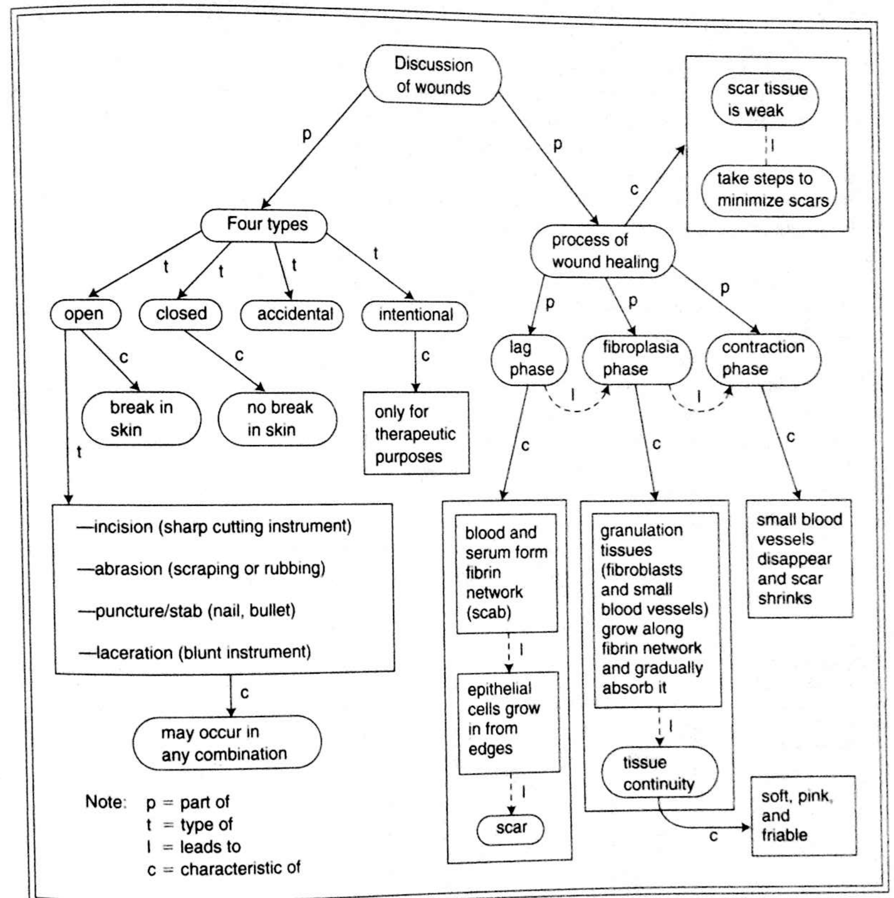

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Figure 11–6 shows how the linking analysis can be used to build a knowledge map for a passage on wounds from a nursing textbook. As you can see, the discussion of wounds can be broken into two major parts: "types of wounds" and "process of wound healing." The types of wounds include "open," "closed," "accidental," and "intentional"; types of open wounds include "incision," "abrasion," "puncture," "laceration"; a characteristic of open wounds is that there is a "break in the skin", and so on. Knowledge mapping involves breaking a passage into parts (i.e., ideas) and then identifying the linking relations among the parts. The result is a graphic representation of the passage, that is, a knowledge map.

Does mapping training affect student learning? To test the effectiveness of mapping training, Dansereau and colleagues (Holley et al. 1979) trained college students to recognize types of links (such as in Figure 11–5), to apply the knowledge mapping procedure to sentences, to apply the mapping procedure to passages, and, finally, to apply the mapping procedure to their own textbooks. Training required approximately 5½ hours spread over four sessions. Mapping-trained students and control students who received no training were then asked to study a 3,000-word passage from a geology textbook. On subsequent tests, including multiple-choice, fill-in, short-answer, and essay questions, the mapping-trained subjects performed much better than the control subjects in remembering the main ideas but not in remembering the details. In addition, the positive effects of mapping training seemed to be particularly strong for students with low grade point averages (GPAs) but not for students with high grade point averages. Apparently, high-GPA students have already developed their own techniques for organizing prose material. These results are summarized in Figure 11–7.

In another study (Dansereau et al., 1979), students who took a learning strategy class that met for twelve 2-hour sessions were compared to a control group. All students were given a pretest and posttest in which they read a 3,000-word textbook passage and answered multiple-choice and short-essay questions. Students who had received training in knowledge mapping showed an improvement from a score of 47 on the pretest to a score of 57 on the posttest, whereas the control subjects averaged a score of 47 on both the pretest

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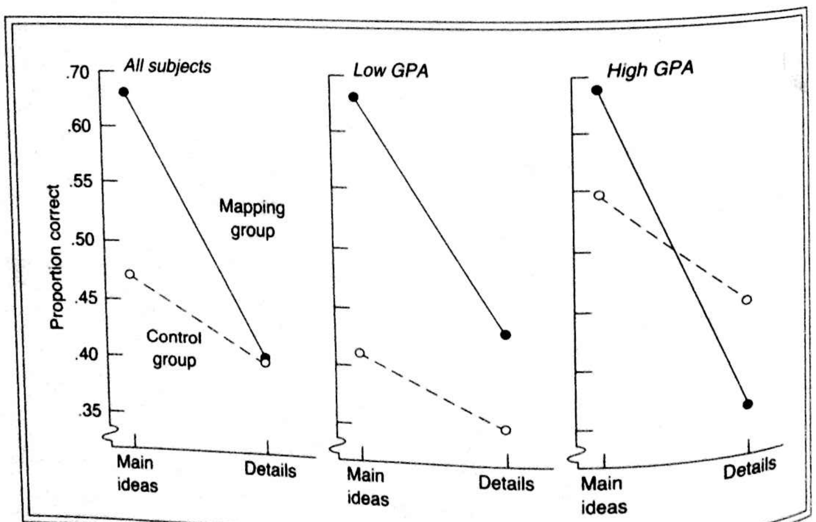


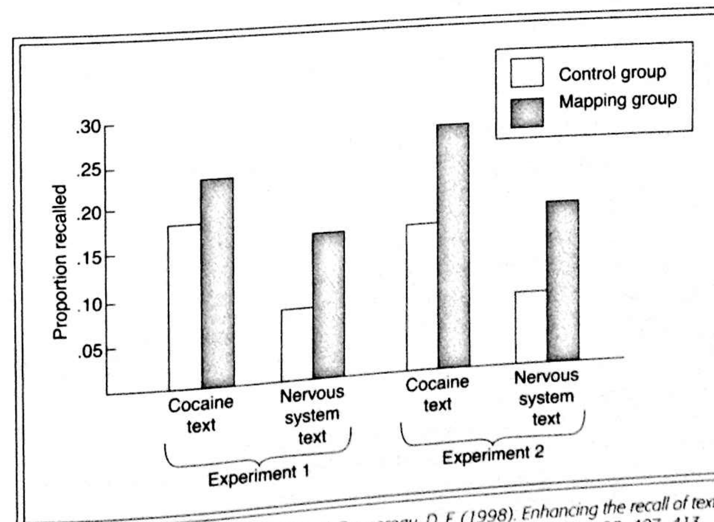
Source: Adapted from C. D. Holley, D. F. Dansereau, B. A. McDonald, J. C. Garland, & K. W. Collins, Evaluation of a hierarchical mapping technique as an aid to prose processing, Contemporary Educational Psychology, *4, pp. 227–237, Copyright © 1979, with permission from Elsevier.*

and the posttest. Other types of strategy training, such as paraphrasing and forming mental images, were not as successful as training in knowledge mapping. Apparently, students can be trained to organize information as they study, and this training is useful for long textbook passages.

In a related set of experiments, Chmielewski and Dansereau (1998) asked students to study a passage about cocaine for 6 minutes and a passage about the nervous system for 6 minutes. For both passages, the students were not allowed to write any notes, and 5 days later, the students were asked to write down all they could recall from the two passages. In previous sessions, some students had received 3 hours of knowledge mapping training (mapping group), whereas other students (control group) had not. Figure 11–8 shows the amount recalled for each passage across two different experiments. On the recall tests, students in the mapping group recalled an average of 60% more of the important ideas than did students in the control group. The results represent an important form of transfer, because students in the mapping group were not actually allowed to draw any knowledge maps for the two passages they studied. Chmielewski and Dansereau conclude that "training participants on the construction and use of knowledge maps positively transfers to text processing when a mapping strategy is not explicitly used" (p. 412).

As you can see, knowledge mapping involves using what Holley and Dansereau (1984) call a *spatial learning strategy*. Another popular spatial learning strategy is *concept mapping* (Novak, 1998) in which students produce maps consisting of nodes (i.e., concepts) and links (i.e., labeled lines between nodes). Unlike in knowledge mapping, the links in concept mapping do not necessarily have to correspond to preestablished types. For example, Figure 11–9 shows a concept map produced by a 6-year-old student after about 30 minutes

FIGURE 11–8
Mapping-trained students recall more from text than control students



Source: Adapted from Chmielewski, T. L., & Dansereau, D. F. (1998). Enhancing the recall of text: Knowledge mapping training promotes implicit transfer. Journal of Educational Psychology, 90, 407–413.

E 11–11 Five top-level structures

-level ıcture	Definition	Example	Signaling words
cription	Gives attributes, specifics, or setting information about a topic; main idea is attributes of a topic	Newspaper article describing who, what, where, when, and how	For example, for instance, specifically, attributes of, properties of, characteristics of
uence	Is grouped on the basis of order or time; main idea is procedure or history	Recipe procedure, history of Civil War battles, growth from birth to 12 months	Afterward, later, finally, last, early, following, to begin with, to start with, then, before, after
usation	Presents cause-and-effect relations; main idea is cause and effect parts	Directions for how to take a photo; explanation of how something works	As a result, because, since, for the purpose of, caused, led to, consequence, so
blem lution	Contains a problem part and a solution part, or a question and answer; main idea is problem and solution or question and answer	Scientific articles that raise a question or problem and then seek to give an answer or solution	Problem, question, puzzle, issue, trouble, solution, answer response, reply, solve
mparison	Compares and contrasts ideas based on differences and similarities; main idea provides comparison or contrast	Political speech comparing two views	In contrast, instead, however, whereas, in comparison, on the other hand, compared to, while, although, despite

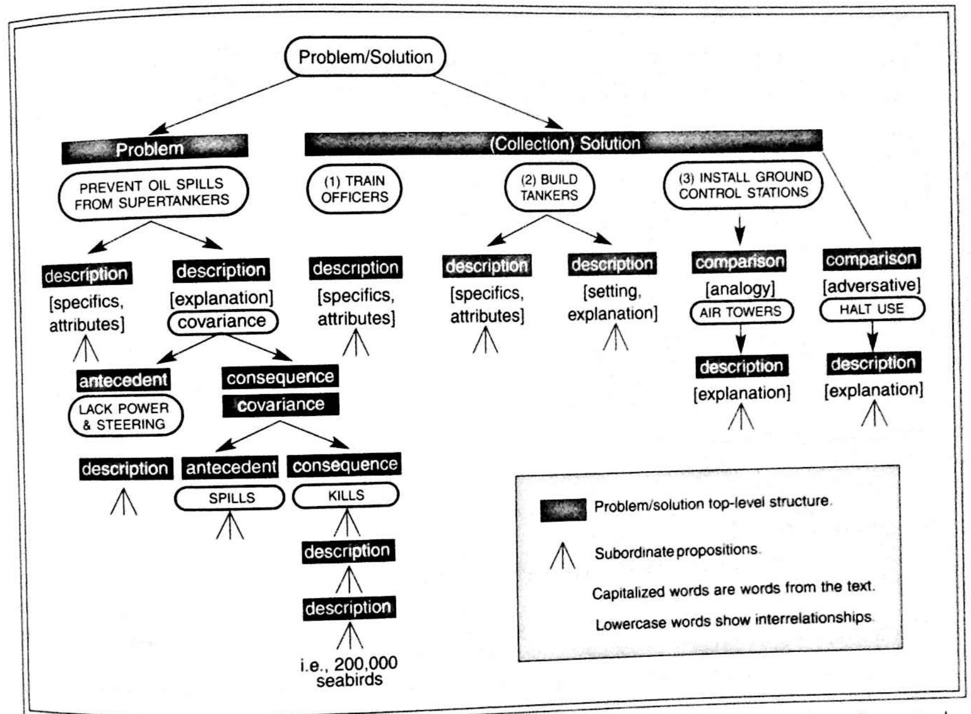
pted from: Meyer, Young, & Bartlett (1989); Meyer and Poon (2001).

> They churned their way up the shallow waters of the Missouri, Ohio, or Mississippi Rivers. Their hulls were flat, without room for cargo. The cargo was carried on the main deck or on the superstructure, one or two floors above the main deck. More efficient and dangerous high-pressure engines were used and often burned up to 32 cords of wood a day. (Meyer & Poon, 2001, p. 157)

First, use Figure 11–11 to determine which type of structure is being used, and then use that structure to guide your notetaking. For each practice passage, Meyer and Poon (2001) asked students to "underline the signaling words that cue us into the author's plan" and "write the name of the plan." Meyer and Poon provided feedback such as the following:

1. Did you pick out the organization as comparison? Did you look for the plan (i.e., contrast between eastern and western steamboats)? Did you find the main idea organized by the plan (i.e., differences between eastern and western steamboats in hull depth, extent of superstructure, cargo location, and type of pressure engine)?
2. Did you write the name of the plan at the top of the recall page?
3. Did you write down the main idea as the first sentence?

FIGURE 11–12 A structural analysis of the supertanker passage



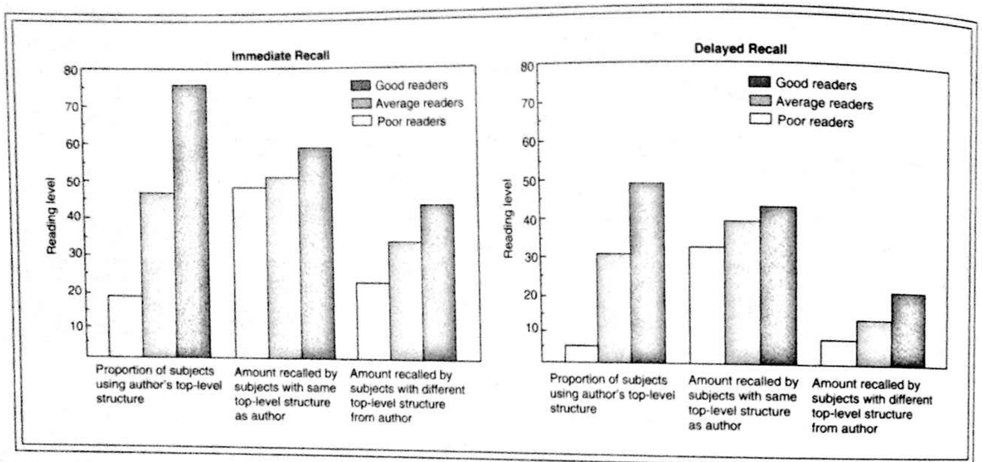
Source: Adapted from Meyer, B. J. F., Brandt, D. H., & Bluth, G. J. (1980). Use of top-level structure in text: Key for reading comprehension of ninth-grade students. Reading Research Quarterly, *16, 72–103. Copyright © 1980 by the International Reading Association.*

4. Did you have two parts in arranging your sentences (one for eastern steamboats and one for western steamboats)?
5. Did you check? (pp. 157–158)

Does strategy training help? When people were tested on a variety of new passages and an instructional video, the structure-trained group outperformed the control group on total recall, recall of the main material, and the quality of their summaries. The results were strong and consistent for both younger and older adults. Similar results were found with fifth graders in which structure training resulted in improvements in recall performance as compared to a control group (Meyer, Middlemiss, Theodorou, Brezinski, & McDougall, 2002) and with second graders for compare/contrast passages (Williams, Hall, Lauer, Stafford, DeSisto, & deCani, 2005).

In a related study, Cook and Mayer (1988) trained students to identify five prose structures that are found in science textbooks: generalization, enumeration, sequence, classification, and

FIGURE 11–13 Role of top-level structure in prose learning



Adapted from Meyer et al. (1980).

compare/contrast. Examples and definitions are given in Figure 11–14. As you can see, Cook and Mayer's prose structures are somewhat different from those suggested by Meyer, although some structures are quite similar. One reason for the differences may be that Meyer's structures are based on general expository prose whereas Cook and Mayer's structures are based on passages found in chemistry, biology, and physics textbooks.

As a first step, Cook and Mayer (1988) conducted a study to determine whether students could be taught to recognize the five structures summarized in Figure 11–14. Some college students (structure training group) were given a booklet that described and exemplified the five structures; other subjects (control group) received no training. Then all subjects were given worksheets containing 20 science passages (i.e., 4 passages for each of the five structure types); subjects were asked to sort the passages into five groups based on the structure of the material (rather than content). Results indicated that the structure training group correctly sorted 79% of the passages, compared to 61% correctly sorted passages for the control group. The next step in Cook and Mayer's project was to provide an extensive training program to junior college students who were taking a chemistry course. The training involved an initial session in which students learned to recognize three types of prose structures—generalization, enumeration, and sequence. Subsequent training involved asking the student to fill out worksheets such as shown in Figure 11–15; the student filled out three worksheets for each of the three structures based on nine sections from the students' chemistry textbook. The instructor provided feedback after each worksheet. In contrast, students from another section of the course received no training and served as a control group.

To assess the effectiveness of the training, Cook and Mayer (1988) gave a pretest and posttest to all students. Each test consisted of reading three passages (i.e., generalization, enumeration, and sequence passages on science material other than chemistry). After reading, students were asked to recall each passage and to answer questions about verbatim

FIGURE 11–14 Five prose structures for science text

Generalization

1. Passage always has a main idea.
2. Most of the other sentences in the passage try to provide evidence for the main idea by either clarifying or extending.
   a. Explain the main idea by using examples or illustrations. These tend to *clarify* the main idea.
   b. Explain the main idea in more detail; extend the main idea.
3. Things to look for: definitions, principles, laws.
4. Reading objectives: Understand the main idea; be able to explain it in your own words, using the supporting evidence.

Example

Irritability is defined as an organism's capacity to respond to conditions outside itself. An organism responds to a stimulus from the environment. The stimulus may be light, temperature, water, sound, the presence of a chemical substance, or a threat to life. The organism's response is the way it reacts to a stimulus.

For example, a plant may have a growth response. This happens when a root pushes toward water or a stem grows unevenly and bends toward light.

Enumeration

1. List facts one after the other.
2. There are two general kinds of enumeration passages:
   a. Specified—actually lists the facts by numbering them.
   b. Unspecified—lists facts in paragraph form, with each fact stated in one or more sentences.
3. It is difficult to produce a single statement that summarizes the information accurately.
4. Reading objectives: Note the general topic; more important, though, is the retention of each subtopic or the individual facts.

Example

There are four general properties of solids:
1. Tenacity is a measure of a solid's resistance to being pulled apart.
2. Hardness is a measure of a substance's ability to scratch another substance.
3. Malleability refers to a solid's ability to be hammered or rolled into thin sheets.
4. Ductility is the ability to be drawn out in the form of wires.

Sequence

1. Describes a continuous and connected series of events or the steps in a process.
2. Examples of sequences include changes as the result of growth, a biological process, steps in an experiment, or the evolution of some event.
3. Signal words: "The first step in," "stages," "and then."
4. Reading objectives:
   a. Be able to describe each step in the sequence.
   b. Be able to tell the differences between each stage or step.

Example

Hearing can be described in five separate stages. First, sound waves are captured by the external portion of the ear. The outer ear's function is to focus or concentrate these sound waves. During the second stage, the sound waves travel down the auditory canal (a tube embedded in the bones of the skull) and strike the tympanic membrane or eardrum. The third stage occurs when the vibrations of the eardrum begin a series of similar vibrations in several small bones. These vibrations are then transmitted to the inner ear (called the cochlea) during the fourth stage. At this point, the vibrations are turned into neural impulses that are sent to the brain. The fifth and final stage of the hearing process represents the brain's interpretation of the sound patterns.

Classification

1. Groups or segregates material into classes or categories.
2. Develops a classification system to be used in the future to classify items.

Example

Experimental variables can be grouped into one of two categories: either a manipulated variable or a controlled variable. A variable that can be acted on directly is called a manipulated variable. The flow of

(continued)

RE 11–14 (continued)

3. Signal words: "can be classified," "are grouped," "there are two types of." 4. Reading objective: a. Know and be able to list class or grouping factors. b. Understand how the classes differ. c. Be able to classify new information.	steam into a room is an example of a manipulated variable, because it can be controlled directly. In contrast, a variable that can't be acted on directly is called a controlled variable. The temperature of a room is an example of a controlled variable because it must be achieved through manipulating another variable. In this case, it must be achieved through manipulating the flow of steam.
Compare/Contrast 1. Primary objective is to examine the relationship between two or more things. 2. Compare means to analyze both the similarities and differences; contrast focuses only on the differences. 3. Signal words include "in contrast to," "the difference between," etc. 4. Reading objective: be able to discuss similarities/differences between things.	*Example* There are two different hypotheses for the origin of the earth: the nebular hypothesis and the comet-produced hypothesis. The nebular hypothesis maintains that our planet began in an aggregation of interstellar gas and dust. This theory is gaining more and more acceptance. In contrast, the comet-produced hypothesis states that the earth began as a piece of the sun that was ripped out by a comet. The first hypothesis assumes the earth began as small elements that combined into larger ones. The latter hypothesis asserts the earth was essentially already formed when it began taking on its present-day characteristics.

urce: From Cook, L. K., & Mayer, R. E. (1988). Teaching readers about the structure of scientific text. Journal of Educational ychology, 80, 448–456. Copyright © 1988 by the American Psychological Association. Reprinted with permission.

details (retention questions) and about applying the information to solve a problem (problem-solving questions). Figure 11–16 summarizes the results. As you can see, the structure-trained group showed an increase in recall of high-level information but not low-level information, as compared to the control group. Similarly, the structure-trained group showed an increase in problem-solving transfer but not in retention of facts, as compared to the control group. Apparently, students can transfer their training in general prose structures to the outlining of new passages, resulting in a more coherent mental organization of the material.

Another way to encourage learners to organize material is to provide a structure for them to use during learning. For example, Kiewra et al. (1991) asked students to view a

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Generalization

Step 1: Identify the generalization (main idea).
  List and define key words in the generalization.
  Word:
  Definition:
  Restate the generalization in your own words.
Step 2: What kind of support is there for the generalization? Does it use examples, illustrations? Does it extend or clarify the generalization?
  Supporting Evidence:
  Relation to Generalization

FIGURE 11–15
(continued)

Enumeration

Step 1: What is the general topic?
Step 2: Identify the subtopics.
  A.
  B.
  C.
  D.
Step 3: Organize and list the details within each subtopic. (Do one subtopic at a time; use your own words.)
  A.
  B.
  C.
  D.

Sequence

Step 1: Identify the topic of the passage.
Step 2: Take each step, name it, and then outline the details within each.
  Step 1
  Step 2
  Step 3
  Step 4
Step 3: Discuss (briefly) what is different from one step to the next.
  Step 1 to 2
  Step 2 to 3
  Step 3 to 4

Source: From Cook, L. K., & Mayer, R. E. (1988). Teaching readers about the structure of scientific text. Journal of Educational Psychology, 80, 448–456. Copyright © 1988 by the American Psychological Association. Reprinted with permission.

FIGURE 11–16
Pretest-to-posttest changes for trained and control groups

Group	*Recall* *Low Level*	*Recall* *High Level*	*Retention of Facts*	*Problem Solving*
Trained	–4%	11%	14%	24%
Control	3%	0%	1%	–3%

Source: From Cook, L. K., & Mayer, R. E. (1988). Teaching readers about the structure of scientific text. Journal of Educational Psychology, 80, 448–456. Copyright © 1988 by the American Psychological Association. Reprinted with permission.

RE 11–17
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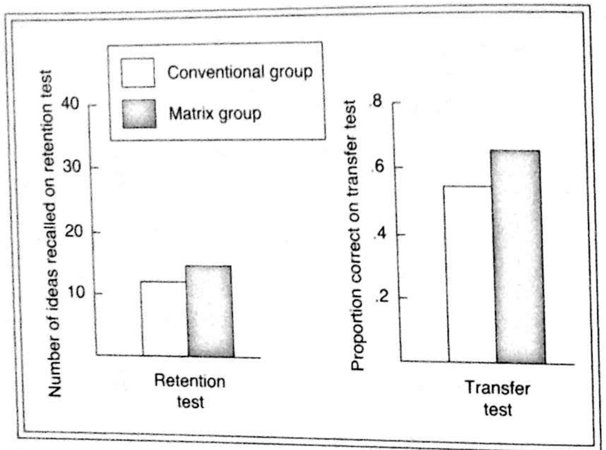


Source: Adapted from Kiewra, K. A., DuBois, N., Christian, D., McShane, A., Meyerhoffer, M., & Roskelley, D. (1991). Note-taking functions and techniques. Journal of Educational Psychology, *83, 240–245.*

19-minute videotaped lecture on creativity. Some students were told to take notes by writing on blank sheets of paper (conventional group), and some were told to take notes by filling in cells of a 5 × 9-inch matrix with the names of five types of creativity printed along the rows and the names of the nine dimensions printed along the columns (matrix group). If the matrix provides cues for how to organize and integrate notes, the matrix group should outperform the conventional group on remembering (retention test) and using the material (transfer test). Figure 11–17 confirms this prediction, with the matrix group remembering 30% more on the retention test and generating 18% more correct answers on the transfer test than the conventional group. These results show that not all notetaking activities are equally productive. When notetaking activity is structured, students appear to learn more deeply.

IMPLICATIONS OF STRUCTURE STRATEGIES

Suppose that students are asked to read a chapter in their science textbook. Some students will read the material and be able to correctly answer questions about the main concepts in the chapter. These students are able to figure out what is important and what is not important. If asked, they would be able to provide an outline of the passage similar to the author's. These students do not need training in structure strategies.

In contrast, other students will read the material, perhaps even carefully read each word, and still not be able to correctly answer questions about the main ideas in the passage. These students are not aware of the way that sections of science books are organized, such as generalization or sequence or classification, and they could not produce a coherent outline of the material. These students seem to be excellent candidates for training in structure strategies.

The research presented in this section shows that students can be taught to use effective strategies for organizing expository material. Two central features of successful training systems are (1) emphasis on specific types of structures commonly found in expository prose, and (2) extensive practice in recognizing and applying these structures when actually reading textbooks.

The initial step in structure training is to give students clear definitions and examples of the major prose structures that they are likely to find in the textbook. This section described two different structure training systems—knowledge mapping and outlining—and both systems began by giving the students clear definitions and examples of a small set of structures. Because different subject matter domains rely on different types of structures (e.g., biology emphasizes classification, whereas chemistry emphasizes sequence), the teacher may choose a few basic structures that are most commonly used in the class's textbook. Students then need practice in recognizing which paragraphs in the textbook correspond to which structures.

The second major step is to help students outline their textbook based on the underlying prose structure. For example, once a student recognizes that a paragraph is generalization, the student should be able to list the main assertion followed by supporting evidence. Feedback from the teacher (or other models) is useful so that the student can compare his or her outline to the teacher's.

Structure strategies are likely to be most useful for less skilled readers (because skilled readers presumably possess better organizing skills) and for unfamiliar expository material (because students have more experience with the structure of stories).

Generative Strategies

WHAT ARE GENERATIVE STRATEGIES?

The preceding sections explored ways to help the learner remember specific facts and organize material into a structure. Another aspect of active learning is integrating the material with existing knowledge. Generative strategies are learning strategies aimed at helping the learner integrate presented information with existing knowledge and experience. For example, in reading the lightning passage (Figure 11–1), we could teach a student to take summary notes or to generate and answer questions.

THEORY: HOW DO GENERATIVE STRATEGIES WORK?

Rothkopf (1970) coined the term *mathemagenic activity* to refer to any activity of the learner that gives birth to knowledge. For example, taking notes, underlining, answering questions, or repeating aloud all are mathemagenic activities. In taking a cognitive perspective, you might ask, "How can such activities promote meaningful learning?" Based on the model of meaningful learning presented in this book, these activities are intended to promote meaningful learning partly because the learner is encouraged to integrate incoming material with existing knowledge. In particular, Wittrock (1974, 1990) argued that learning is a generative process in which the learner must actively generate the relations among ideas—activities that I have called building internal and external connections. Some learning activities such as notetaking may help some students engage in generative processing.

RESEARCH: DO GENERATIVE STRATEGIES WORK?

Consider the following scenario: You enter a lecture hall where the professor is giving a lecture on the formation of lightning. You sit down and glance at the notes of the student sitting on your right. She has written a series of verbatim phrases from the instructor such as "cool, moist air" on one line, "forms a cloud" on the next line, "reaches freezing level" on the next line, and so on. To her, notetaking seems to involve selecting relevant facts to write down. You look to the student on your left. He has written a sort of outline consisting of five major steps labeled 1 through 5, and under each he has listed some component processes labeled by letters such as a, b, c. To him, notetaking seems to mean organizing relevant facts into a structure. Finally, you look over the shoulder of the student in front of you. She has written a summary in her own words describing how lightning forms, and in the margin she has written some comments based on her own knowledge (such as "positive and negative charges attract"). To her, notetaking seems to mean trying to elaborate on the material and relate it to what she already knows.

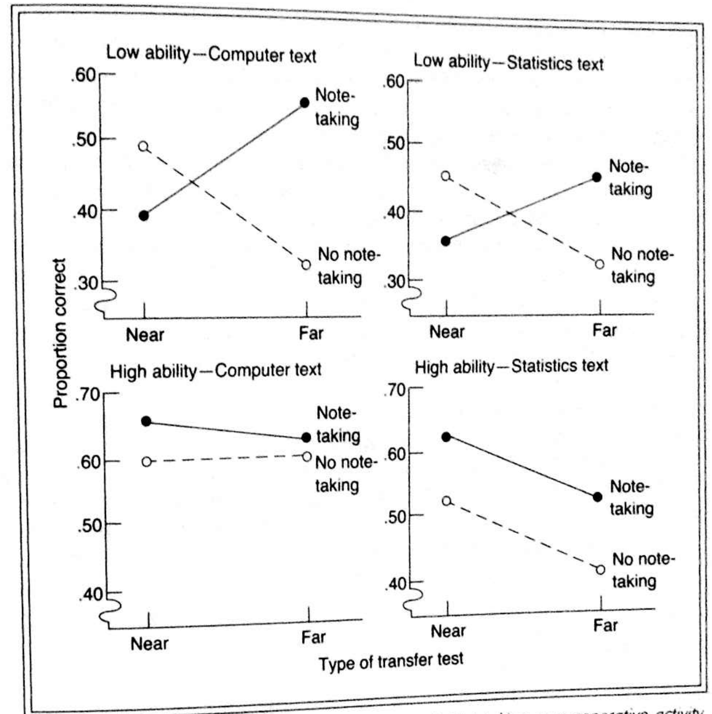
This section focuses mainly on aspects of notetaking reflected in the third student—using notetaking as a way to integrate the presented information with past experience. Generative strategies are intended to promote deep understanding by prompting the learner to put the material into his or her own words, distill its main message, and relate it with other knowledge. Two important generative strategies are summarizing and questioning.

Summarizing Strategies Under some conditions, notetaking may help the learner build external connections (i.e., to relate the information presented to existing knowledge). The learner may be encouraged to explain an idea in his or her own words or to relate information to a familiar concrete model. For example, Mayer (1980) asked college students to read a manual on computer programming with one programming command described on each page. For some students, after each page they were asked to explain the command in their own words and relate it to a concrete familiar situation (elaboration group). Other students read each page without elaborating (nonelaboration group). Students in the elaboration group tended to recall more conceptual information from the booklet and to perform better on problem-solving tests that involved applying commands to new tasks than did the nonelaboration group. However, the nonelaboration group performed just as well as the elaboration group on recall of details from the manual and on solving problems like those given in the manual. Apparently, elaborative notetaking encouraged readers to relate the presented information to what they already knew, resulting in meaningful learning.

In a similar series of studies, Peper and Mayer (1978) asked college and high school students to view a 15-minute videotaped lecture on computer programming or statistics. Some students were asked to take notes during the lecture; while others were not allowed to take notes. Following the lesson, students were given problem-solving tests that included problems like those given during the lecture (near transfer) and problems that required creative use of the information in new situations (far transfer).

Figure 11–18 shows that for low-ability subjects, the notetaking group excelled on far transfer, whereas the non-notetaking group excelled on near transfer. For high-ability subjects, notetaking increased performance by a modest amount on both types of questions. If

FIGURE 11–18
Effects of notetaking on creative problem solving



Source: Adapted from Peper, R., & Mayer, R. E. (1978). Notetaking as a generative activity. Journal of Educational Psychology, *70,* 514–522.

notetaking served mainly to focus the learner's attention, we would expect superior performance on problems like those given in the lesson; if notetaking served mainly to elicit integrative processing (i.e., building external connections), we would expect better performance on tests of creative transfer. Thus, the increase in far transfer performance is most consistent with the idea that notetaking in this study resulted in building external connections.

In addition, subsequent recall tests revealed that notetakers excelled mainly on recall of conceptual information but not on recall of specific details and that notetakers produced more "intrusions" about information that was not in the booklet. If notetaking served mainly to focus attention on the main facts in the lesson, we would expect better recall of specific facts. If notetaking helped the learner construct coherent external connections, we would expect better recall of the basic conceptual principles in the passage. These results are consistent with the idea that when appropriate dependent measures—such as far transfer or recall of concepts—are used, evidence for integrative processing emerges.

Some more restricted forms of notetaking may not elicit the building of external connections. For example, Mayer and Cook (1981) asked students to listen to a passage about how radar works. Some were asked to repeat each phrase verbatim during pauses in the presentation. Verbatim shadowing of the passage resulted in poorer recall for the conceptual principles and in poorer performance on creative problem solving than in a control group that simply listened to the passage. Thus, verbatim copying seems unlikely to lead to the building of external connections even though the learner is being forced to be behaviorally active.

Other ways of encouraging students to construct external connections (as well as internal connections) in a passage include summary notetaking. In a summary notetaking study, Doctorow, Wittrock, and Marks (1978) asked elementary school students to read a passage and then recall the passage. Some students were asked to generate a summary sentence that expressed the main idea for each paragraph (summary group); some students were given a two-word heading for each paragraph that summarized the main idea (heading group); some students received both treatments (summary and heading group); and some subjects read the passage without headings or summary notetaking.

Figure 11–19 summarizes the results on a subsequent retention test for good readers who were given a 1,125-word passage for 20 minutes and for poor readers who were given a 372-word passage for 8 minutes. As Figure 11–19 shows, for both good and poor readers, the summary group retained over 50% more information than did the control group, and this advantage was enhanced when headings were provided for each paragraph. Wittrock (1974) argued that subjects who write summaries engage in generative learning—generating connections among ideas in the passage rather than memorizing specific words.

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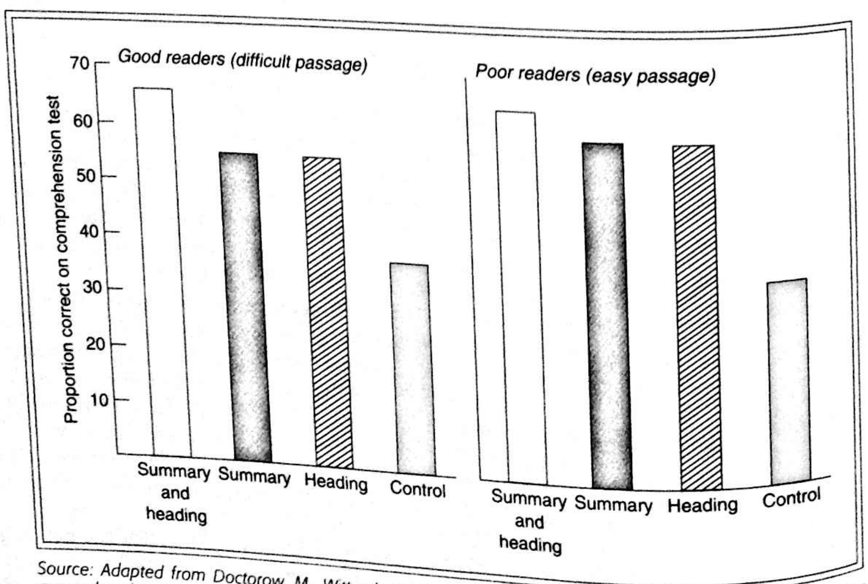
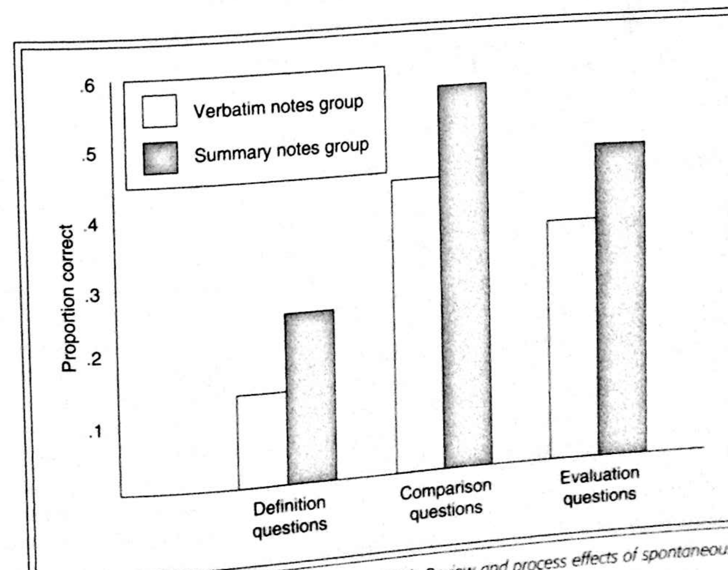


Source: Adapted from Doctorow, M., Wittrock, M. C., & Marks, C. (1978). Generative processes in reading comprehension. Journal of Educational Psychology, 79, 109–118.

Suppose students are asked to take notes in any way that would help them as they read a philosophy text. As a result, some students write verbatim words and phrases (verbatim notes group), whereas other students summarize the main ideas in their own words (summary notes group). Which form of notetaking is more effective? If summary notes require deeper processing by the learner (including organizing and integrating the material), you would expect the summary notes group to outperform the verbatim notes group on being able to use the presented information to answer essay questions. This is exactly what happened in a study by Slotte and Lonka (1999). For example, Figure 11–20 shows the essay test scores on defining key concepts, comparing and contrasting several different ideas, and evaluating the author's views on a given topic. As you can see, for each type of essay question, students who opted to take summary notes outperformed students who opted to take verbatim notes. These results are consistent with the observation that all notetaking activities are not equally useful ways to promote transfer. It appears that notetaking is more likely to promote transfer when learners generate summaries in their own words rather than copy verbatim words and phrases.

What can be done to help students reflect on their notes and organize them into coherent summaries? To study this issue, King (1992) presented students with a 20- to 30-minute social science lecture on a topic such as "civil liberties" and asked them to take notes. The students were involved in a remedial study skills course and had been selected because of their relatively low-verbal-ability scores. During a subsequent study period, some students (note-taking-with-review group) were told to prepare for a test by reviewing their notes, whereas other students (note-taking-with-summarizing group) were told to prepare for a test by using their notes and recollections to write a summary of the main points from the lecture. Students in the notetaking-with-summarizing group were taught

FIGURE 11–20
Students who take summary notes produce better answers to transfer questions than students who take verbatim notes



Source: Adapted from Slotte, V., & Lonka, K. (1999). Review and process effects of spontaneous notetaking on text comprehension. Contemporary Educational Psychology, 24, 1–20.

how to write a summary by writing a sentence stating the main point and then writing sentences linking the main point of each subtopic back with the main topic. In addition, they were told to write using their own words. These activities appear designed to help students select relevant ideas (by choosing the points to be summarized), organize them into a coherent structure (by linking the subtopics to the main topic), and integrate them with prior knowledge (by writing in one's own words). Students who were taught to summarize their notes actually took more complete notes than those who were not, perhaps in anticipation of the summarization activity. Specifically, the notetaking-with-summarizing group had 29% more of the important ideas in their notes than did the notetaking-with-review group. What happened after the groups reviewed or summarized their notes? On a comprehension test for the lecture, the notetaking-with-summarizing group scored 25% higher than the notetaking-with-review group. These results show that students can learn how to be active notetakers in ways that are more likely to promote deep learning.

In a review of programs aimed at teaching students how to write summaries, Pressley and Woloshyn (1995) concluded that "summarization training is a powerful intervention" (p. 62). Furthermore, Peverly, Brobst, Graham, and Shaw (2003) provide evidence that college students need training in how to take notes for difficult material.

Questioning Strategies Listening to a lecture or reading a textbook chapter may appear to be a passive activity. How can we turn it into an active learning experience in which the learner tries to make sense of the material? One approach is to teach students how to generate and answer appropriate questions as they learn.

A first step is to examine what successful learners do as they read a textbook. Chi, Bassok, Lewis, Reimann, and Glaser (1989) compared how successful and less successful students read a physics lesson that included worked-out problems. Students were asked to talk aloud as they read. For example, they might say "Ummm, this would make sense because they're connected by a string that doesn't stretch" or "If the string's going to be stretched, the earth's going to be moved, and the surface of the incline is going to be depressed." In these comments, you can see that the students are trying to explain the worked-out problems to themselves, creating what Chi et al. call *self-explanations*. In creating self-explanations, students turn the seemingly passive task of reading a textbook lesson into an active task of sense making. Importantly, students who were successful in solving physics problems generated five times as many self-explanations while reading as did the less successful students. These results suggest that successful learners are more likely to know how to engage in active cognitive processing during learning—that is, they ask themselves questions and answer them.

If successful problem solvers are more likely to engage in self-explanations while learning, what would happen if we encourage inexperienced students to engage in generating self-explanations? To examine this question, Chi, De Leeuw, Chiu, and LaVancher (1994) asked eighth graders who had never taken a biology course to read a 101-sentence passage on the human circulatory system. Some students were told to explain what each sentence means after reading it (self-explanation group), whereas others were told to repeat each sentence after reading it (control group). Students in the self-explanation group showed a much greater improvement on transfer questions than did the control group. These transfer questions required making inferences that went beyond simple retention of the facts, such as "Why doesn't the pulmonary vein have a valve in it?" Subsequent interviews revealed that 57% of the self-explanation group developed an accurate mental model of how the human circulatory system works, compared to 22% for the control group. Developing an accurate mental model is an indication of meaningful learning and is useful for solving problem-solving transfer problems. Apparently, students learned more deeply when they were required to engage in explaining text as they read.

The self-explanation results encourage the idea that low-achieving students might benefit from training in how to generate and answer appropriate questions as they read a textbook or listen to a lecture. In an exemplary study, King (1992) taught self-questioning skills to college students who had been diagnosed as having learning difficulties. First, the students were given a list of 13 general questions, as listed in Figure 11–21. King (1992) designed the questions to "guide students in processing the lecture content by . . . analyzing

FIGURE 11–21
A Questioning Strategy

QUESTIONS	*COGNITIVE PROCESSES THE QUESTIONS ARE INTENDED TO INDUCE IN LEARNERS*
Explain why _____	analysis of processes and concepts—explicit or implicit in the lecture
Explain how _____	translating terms into different vocabulary
What is the main idea of _____ ?	identification of central idea explicit or implicit in the lecture
How would you use _____ to _____ ?	application of information in another context—perhaps relating to prior knowledge or experience
What is a new example of _____ ?	generation of novel examples of a concept or procedure—perhaps involving relating to prior knowledge or experience
What do you think would happen if _____ ?	retrieval of background knowledge and integration with lecture material to make predictions
What is the difference between _____ and _____ ?	analysis of two concepts—comparison and contrast of concepts
How are _____ and _____ similar?	analysis of two concepts—comparison and contrast of concepts
What conclusions can you draw about _____ ?	drawing conclusions based on the content presented
How does _____ affect _____ ?	analysis of relationships among ideas
What are the strengths and weaknesses of _____ ?	analysis and integration of concepts
What is the best _____ and why?	evaluation of ideas based upon criteria and evidence
How is _____ related to _____ that we studied earlier?	activation of prior knowledge and integration with new information

Source: From King, A. (1992). *Comparison of self-questioning, summarizing, and notetaking-review as strategies for learning from lectures.* American Educational Research Journal, 29, 303–323.

the ideas and concepts in the lecture, determining how those ideas relate to each other, and relating new information to their own prior knowledge or experience" (p. 309). The instructor modeled (a) how to use the general questions to generate specific questions relevant to a specific lecture and (b) how to answer the specific questions based on the lecture content. Next, the students worked individually to generate questions and answers. The students shared their questions and answers with the class and received constructive feedback. Finally, they practiced by taking notes on a short lecture and then generating questions and answers based on their notes.

Does training in self-questioning affect learning from a lecture? To test this question, King (1992) asked students to take notes on a 20- to 30-minute lecture on a social science topic such as "civil liberties" and then review the notes (notetaking with review) or engage in self-questioning (notetaking with questioning). The lecture notes of the notetaking-with-questioning group contained 33% more of the important ideas than did the lecture notes of the notetaking-with-review group, suggesting that the questioning training helped students focus on the important material. In addition, the notetaking-with-questioning group generated 13% more correct answers on a comprehension test (involving transfer) than did the notetaking-with-review group, suggesting that questioning helped students learn more deeply.

If your goal is teaching for transfer, the process of generating and answering thought-provoking questions can help learners reflect on the presented material. For example, King, Staffieri, and Adelgais (1998) taught middle school students how to ask a series of thought-provoking questions based on science lessons. The questioning pattern begins with a knowledge-review question such as "How does the muscular system work, Kyle?" and follows up with probing questions such as "Can you tell me more?" and hint questions such as "Why are muscles important?" Students worked in pairs taking turns as question asker and question answerer. Figure 11–22 gives a portion of a transcript involving Kyle (who serves as the question asker) and Jon (who serves as the question answerer).

Students who participated in generating and answering questions about science lessons (questioning group) performed about as well as other students (no-questioning group) on remembering the factual material—the scores were 66% correct versus 63% correct, respectively. However, on tests of problem-solving transfer in which students had to make inferences, the questioning group scored 68% higher than the no-questioning group—the scores were 57% versus 34%, respectively. Overall, this research shows how questioning strategies can be used to promote deep understanding that leads to transfer. In this case, questions prime more than simply selecting relevant information; it appears that skillfully used questions can guide the process of organizing and integrating knowledge.

This research shows that an effective strategy for promoting generative processing is to teach students to engage in self-explanations—producing oral explanations of textbook material they are reading. Although some students spontaneously generate self-explanations when they are asked to "think aloud" as they read a textbook lesson, some students do not. Importantly, students who spontaneously produce high-quality self-explanations perform better on tests on the material, including tests involving deep understanding (Chi, 2000; Roy & Chi, 2005). For example, suppose you are reading a 19-page lesson on geometry proofs, including the segment shown in Figure 11–23. You are asked to think aloud—that is, to talk about what you are thinking as you the read the materials, and if you remain quiet for more than 5 seconds you are reminded to think aloud. If you engage in generative processing we would expect your thinking-aloud protocol to contain high-quality self-explanations such as management statements, in which you identify a text element as new, monitor your

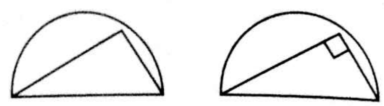
FIGURE 11–22
Using questions to guide learning

	PORTION OF TRANSCRIPT	TYPE OF QUESTION OR COMMENT
Jon:	How does the muscular system work, Kyle?	knowledge-review question
Kyle:	Well . . . it retracts and contracts when you move.	comprehension statement
Jon:	Can you tell me more?	probing question
Kyle:	Um . . . well . . .	
Jon:	Um, why are muscles important, Kyle?	hint question
Kyle:	They are important because if we didn't have them we couldn't move around.	comprehension statement
Jon:	But . . . how do muscles work? Explain it more.	probing question
	Can you give an example?	probing question
Kyle:	Um, muscles have tendons. Some muscles are called skeletal muscles. They are in the muscles that—like—in your arms—that have tendons that hold your muscles to your bones—to make them move and go back and forth. So you can walk and stuff.	comprehension statement
Jon:	Good. Alright!	feedback (accuracy and praise)
	How are the skeletal muscles and the cardiac muscles the same?	thinking question
Kyle:	Uhh—the cardiac and the smooth muscles?	
Jon:	The cardiac and the skeletal.	
Kyle:	Well, they're both a muscle. And they're both pretty strong. And they hold things. I don't really think they have much in common.	knowledge construction (integration, similarities)
Jon:	Okay. Why don't you think they have much in common?	probing question
Kyle:	Because the smooth muscle is—I mean the skeletal muscle is voluntary and—the cardiac muscle is involuntary. Okay, I'll ask now.	knowledge construction (integration, differences)

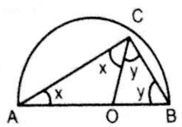
Source: From King, A., Staffieri, A., & Adelgais, A. (1998). Mutual peer tutoring: Effects of structuring tutorial interaction to scaffold peer learning. Journal of Educational Psychology, 90, 134–152.

Angle in a semicircle theorem

The angle in a semicircle is a right angle



Proof



Let C be any point on a semicircle (other than at A or B) where AB is its diameter.

Let <CAB be x and <CBA be y. Join OC.

In OAC,

OA = OC (equal radii)

∴ OAC is isosceles

∴ <ACO = <CAO = x (equal base angles)

Likewise, BOCV is isosceles and ∴<BCO = y.

In ΔABC,

$x + (x + y) + y = 180°$ [sum of angles of triangle]

$\therefore\ 2x + 2y = 180°$

$\therefore x + y = 90°$

Hence angle ACB is a right-angle.

Source: Reprinted from Learning and Instruction, 12, *R. M. F. Wong, M. J. Lawson, & J. Keeves, The effects of self-explanation training on students' problem solving in high-school mathematics, pp. 233–262, Copyright © 2002, with permission from Elsevier.*

comprehension, or evaluate a step in the solution; access statements, in which you remember relevant prior knowledge that was not mentioned in the lesson; and generation statements, in which you create new connections or relations. When Wong, Lawson, and Keeves (2002) asked high school students in Australia to think aloud as they read the lesson, they tended to produce few high-quality self-explanations and they performed poorly on a posttest in which they solved geometry problems. Apparently, students did not engage in much generative processing and they did not learn much from the lesson.

What can we do to encourage students to study the material more deeply. Wong, Lawson, and Keeves (2002) taught some students how to produce high-quality self-explanations. For each section of the lesson, students were told to answer three questions:

1. What parts of this page are new to me?
2. What does the statement mean?
3. Is there anything I still don't understand?

To make sure they understood how to generate answers to these questions, they listened to a student successfully answer the self-explanation questions in a demonstration involving different material. Figure 11–24 shows that students in the trained group generated approximately twice as many self-explanation statements during learning from the lesson than did students in the control group. Importantly, the trained group also scored higher than the control group on a posttest involving solving geometry problems. This

FIGURE 11–24 Students who are trained in generating self-explanations produce more high-quality self-explanations during learning and show greater gains in problem-solving performance

	Trained group	Control group
Self-explanation statements during learning		
Management statements	58	21
Access statements	35	20
Generation statements	42	22
Problem-solving test		
Percentage correct on pretest	61%	61%
Percentage correct on posttest	75%	61%

Source: Reprinted from Learning and Instruction, 12, *R. M. F. Wong, M. J. Lawson, & J. Keeves, The effects of self-explanation training on students' problem solving in high-school mathematics, pp. 233–262, Copyright © 2002, with permission from Elsevier.*

experiment encourages the idea that self-explanation activities can be taught to students who don't spontaneously use them, and that the training can result in deeper learning.

Self-Regulated Learning Strategies Overall, teaching of summarization strategies and teaching of questioning strategies are attempts to help students develop into *self-regulated learners*—learners who take responsibility for managing their learning activities (Azevedo & Cromley, 2004; Winne, 2001). Self-regulated learners are particularly needed in the information age, where students are exposed to many sources of information in many different forms. For example, suppose you are seated at a computer that is running a multimedia encyclopedia, and I ask you to learn all you can about the human circulatory system in 45 minutes. Here are your main instructions:

> You are being presented with a hypermedia encyclopedia, which contains textual information, static diagrams, and digitized video clip of the circulatory system. Your task is to learn all you can about the circulatory system in 45 minutes. We ask you to think aloud continuously while you use the hypermedia environment to learn about the circulatory system. (Azevedo & Cromley, 2004, p. 526)

To get you started, I show you the three most relevant articles—on blood, the heart, and the circulatory system—which together contain 16,900 words, 107 hyperlinks, and 35 illustrations (including diagrams, photos, and animation).

Learning in a hypermedia environment can be a daunting task, so students may not learn effectively. Is there anything we can do to help students learn more effectively? Azevedo and Cromley (2004) developed a 30-minute pretraining lesson that pinpointed some generative learning strategies, such as how to set learning goals, activate prior knowledge, ask questions about the material, elaborate on the material, assess the adequacy of the information, assess how well you are learning, summarize the material, and seek relevant new information (as shown in Figure 11–25).

Did the learning strategy training help college students learn from the multimedia encyclopedia? First, let's examine whether there were differences in strategy use during the 45-minute learning session in which students used the online encyclopedia to learn about the circulatory system. Based on observations of students' behavior and students' thinking-aloud comments during learning, Azevedo and Cromley (2004) found that the

FIGURE 11–25
Some learning strategies performed by students using a multimedia encyclopedia

Learning strategy	Example
Asking questions	Learner spends time reading text and then says: "What do I know from this?" and reviews same content.
Summarizing	Learner says: "This says that white blood cells are involved in destroying foreign bodies."
Drawing	Learner draws diagram after saying: "I'm trying to imitate the diagram as best as possible."
Taking notes	Learner copies text from encyclopedia and says: "I'm going to write that under 'heart.'"
Reading notes	Learner refers to notes and says: "Carry blood away. Arteries—away."
Making inferences	Learner sees diagram of heart and says: "So the blood . . . through the . . . then goes from the atrium to the ventricle . . . and then . . . "
Planning	Learner says: "First, I'll look around to see the structure of the environment and then I'll go to specific sections of the circulatory system."
Assessing learning	Learner says: "Let me read this again since I'm starting to get it . . . "
Activating prior knowledge	Learner says: "I vaguely remember learning about the role of blood in high school."
Managing time	Learner says: "I'm skipping over that section since 45 minutes is too short to get into the details."

Adapted from Azevedo and Cromley (2004).

strategy-trained learners were more likely than the nontrained learners to engage in generative learning strategies such as asking themselves questions, summarizing, drawing, taking notes, reading notes, and making inferences. Second, let's examine what happens to students' conceptions of how the circulatory system works based on asking them both before and after learning to "write down everything you can about the circulatory system" and to draw the path of blood flow throughout the body. Azevedo and Cromley scored each student's answers as reflecting one of 12 progressively more developed conceptions (or mental models) of how the circulatory system. On the pretest, both groups started at the same low level—a version of the single-loop model in which blood circulates through the body with the heart as a pump (level 6). On the posttest, the strategy-trained group showed a much better improvement than did the control group: On average, at the end of learning, the control group still had a version of the single-loop model albeit a slightly more sophisticated version (level 8), whereas the strategy-trained group had a version of the double-loop model (level 10) in which both the heart and the lungs are involved. Thus, on average, the strategy-trained students were more likely to build the double-loop model (which is largely correct), whereas the nontrained students were more likely to build a version of the single-loop model (which is seriously flawed). Third, let's see if the groups differed in their learning of the basic facts, such as being able to label the names of 20 elements on a color picture of the circulatory system. Students in the strategy-trained group showed a much greater prestest-to-posttest improvement (from 5% to 38% correct) than did the control group (from 4% to 23% correct). Overall, the strategy-trained students used more useful generative strategies during learning, performed better on transfer tests (measuring understanding), and performed better on retention tests (measuring memory for main facts).

These results show that it is possible to teach students to become self-regulated learners—that is, learners who take responsibility for controlling their own learning strategies. When learners engage in self-regulated learning they set goals for their learning and then attempt to monitor, regulate, and control their cognitive processing during learning (Azevedo & Cromley, 2004; Winne, 2001). Self-regulated learning is particularly important for learning in hypermedia environments, because learners have so many choices. As you can see, self-regulated learning involves having useful learning strategies (including generative strategies) and being able to manage them. Azevedo and Cromley's study encourages the idea that we can provide direct instruction in learning strategies that promote self-regulated learning.

Each academic discipline may require its own set of generative learning strategies. For example, Wineburg (1991) has shown that expert historians engage in three strategies while reading historical documents: *sourcing heuristic*, in which historians use the source of the document to interpret the content of the document; *corroboration heuristic*, in which historians compare content across documents to identify discrepancies; and *contextualization heuristic*,in which historians place the content within the its spatial-temporal context. However, high school students do not spontaneously use these three strategies (Wineburg, 1991) and even college students can benefit from training in how to use them (Britt & Aglinskas, 2002; Rouet, Britt, Mason, & Perfetti, 1996).

For example, suppose you were given access to a set of six or seven documents about the United States building a canal in Panama in 1903, including historical commentary, participant reports, and excerpts from a novel. Each document is on a separate page and information about the source (e.g., a U.S. president, a novelist, a historian, etc.) is printed at the bottom of each page. You are asked to comprehend the material so you could answer questions such as "What happened during the planning of the Panama revolution?" and "To what extent did the U.S. government influence planning of the revolution?" If you are like most college students who engaged in this task, you probably would not pay much attention to sourcing information such as "Which document was written earliest?" or "Which document is least trustworthy?" In Britt and Aglinskas's (2002) study college students were able to correctly answer an average of 16% of questions about sourcing and high school students correctly answered 12%.

Given the students' low sensitivity to source information, Britt and Aglinkas (2002) developed a computer-based training program called *Sourcer's Apprentice*. The Sourcer's Apprentice program explicitly taught students to identify and use source information when reading documents. When reading documents, for example, students are prompted to take notes on the author (including the author's position and motives), document (including the date), and content (including links to other documents). On the posttest, students examined a different set of materials than those used during training, and were asked sourcing questions. Students who had received the Sourcer's Apprentice training generated twice as many correct answers on the posttest than those who did not receive the training. When asked to write an essay about the materials they read for the posttest, students who had received the Sourcer's Apprentice training generated more than four times as many references to the documents and more than five times as many causal statements. These results show that it is possible to help students improve their skills at identifying and using source information when reading documents. In light of the explosion in information that is available to students through electronic searches, Rouet (2006) has argued that the concept of literacy should be expanded to include skills of document use such as being able to evaluate the credibility and motives of the author and to compare documents.

IMPLICATIONS OF GENERATIVE STRATEGIES

Suppose that a class is listening to a lecture on American history. Does listening mean that learning must be a passive process in which the students simply take the teacher's words and put them into their memories? This section showed that learning—even learning from lecture—can be an active process. The student can control the learning process by using generative techniques such as summarizing, questioning, and self-regulating.

When the goal of instruction is verbatim retention of specific facts, verbatim copying (or underlining in textbooks) guides the learner's attention. When the goal of instruction is retention of important material and transfer, students need to engage generative activities aimed at building connections among ideas.

The active cognitive processing elicited by generative activities such as summarizing, questioning, and self-regulating presumably can be taught. Some students spontaneously take a generative stance and do not need training in generative strategies. Other students engage in generative activities only when told to do so. These students need practice in generative activities such as summarizing, questioning, and self-regulating and in seeing that these activities can improve their test performance. Finally, some students do not know what it means to be an active learner. These students may benefit from direct instruction and practice in generative activities and in comparing their summaries or questions to those of the teacher or other students.

In summary, an activity such as notetaking is not necessarily a mindless chore with little benefit to the learner. On the contrary, in learning to productively take notes, a student can learn how to control his or her cognitive processes, including guiding attention, organizing in what is presented, and relating what is presented to what he or she already knows.

Chapter Summary

This chapter explored three types of learning strategies—mnemonic strategies aimed at increasing the amount of information learned, structure strategies aimed at helping students build internal connections, and generative strategies aimed at helping students build external connections. The building of internal and external connections allows for meaningful learning that enables the student to transfer what was learned to new situations.

Several mnemonic strategies repeatedly have been shown to be successful, including the keyword method, which we explored in this chapter. However, developmental differences are evident in students' ability to learn and spontaneously use mnemonic strategies.

Structure strategies such as mapping and outlining can also successfully help students mentally organize presented material. This kind of training seems to have its strongest effects on transfer performance. Chapter 10 provides some additional examples of research on the role of text adjuncts designed to help learners see the organization of the material.

Generative strategies, including summarizing, questioning, and self-regulating, are aimed at building external connections and show their strongest effects on tests of transfer. Chapter 10 provides some additional examples of research on the role of text adjuncts designed to help learners integrate new material with their prior knowledge.

The theme of this chapter is that teaching of learning strategies is an appropriate instructional activity, although in practice little time is devoted to teaching students how to learn (Weinstein & Mayer, 1985). Teaching students how to remember information, how to determine what is important, or how to figure out the theme of a passage may be just as important for the student's academic success as teaching specific facts and concepts. This chapter showed how learning strategies can be taught effectively within regular subject matter contexts (i.e., using textbook material that is part of the regular program). In the course of teaching science or history, for example, the teacher can also help the student learn how to effectively read, process, and remember the material in a textbook.

The appropriateness of learning strategy training also depends on the teacher's goals. When the goal is to help students memorize paired associates as in foreign language vocabulary, mnemonic strategies are warranted. When the goal is to teach students how to figure out what is important and what is not important in a passage, structure strategies are called for. When the goal is to determine the theme of the passage, generative strategies can be taught. The appropriateness of any strategy training also depends partly on the learner (e.g., whether the learner would normally use the strategy). Before strategy training is carried out, each student should be tested to determine whether he or she knows how to use a particular strategy. If a student is already proficient in using a strategy, training is not needed for that student.

SUGGESTED READINGS

Pressley, M., & Woloshyn, V. (1995). *Cognitive strategy instruction* (2nd ed). Cambridge, MA: Brookline Books. (Reviews research on teaching of learning strategies.)

Rouet, J.-F. (2006). *The skills of document use*. Mahwah, NJ: Erlbaum. (Explores research on teaching of information-gathering strategies.)