

# Cognitive Learning I: Understanding Effective Thinking

This chapter will help you answer the following questions about your learners:

- How can I teach my learners to become good thinkers?
- What cognitive learning strategies can help my learners remember what I teach?
- What cognitive learning strategies can help my learners improve their comprehension of what they read?
- Which is more important to how much my learners are able to learn: prior knowledge or intelligence?
- How can I use the information processing model of thinking to better understand how learning occurs?
- What are some ways of getting and holding my learners' attention?
- What teaching strategies can I use to enhance my learners' reception, availability, and activation of the information I present?
- Do my learners have to learn in orderly, sequential ways or can they use different sources of information simultaneously to construct their own meanings?

• Is my learners' intelligence fixed, or is it made up of many specific abilities that I can improve through instruction?

In this chapter you will also learn the meanings of these terms:

automaticity cognitive strategies comprehension monitoring decay theory declarative knowledge displacement theory domain-specific knowledge dual-coding theory elaboration general knowledge immediate memory information processing model interference theory keyword method long-term memory metacognition organization parallel distributed processing model procedural knowledge propositional networks rehearsal schema theory working memory

Many years ago in the village of Gidole in southern Ethiopia, there lived an old man and his three sons. The old man knew that he had only a few more years to live and he wanted to make sure that his property and possessions were left in good hands. He decided that he would leave all his worldly goods to the most intelligent of his three sons. The problem was finding out which son was the most intelligent.

One day he called his three sons to his bedroom and gave them each a dollar. He told them to go out and buy something with the dollar that would fill the entire bedroom. Then he told them that the son who could do this would inherit all his wealth.

The oldest son, Girma, went to the marketplace and bought as much hay as a dollar could buy. He carted it to the house and brought it to his father's room. But the hay filled only a corner of the room.

The second eldest son, Abebe, looked at the space taken up by the hay, thought a little, and ran out into the countryside. He bought as many large banana leaves as a dollar could buy. He carried them in a cart to his father's house and brought them to his father's room. Alas, the banana leaves filled only half of the room.

The youngest son, Tesfaye, looked at the space taken by the hay. He looked at the space taken up by the banana leaves. Then he looked at the dollar in his hand. His eyes roamed slowly over the entire room. He thought and thought. Then a smile came over his face. He ran to the market and purchased a candle and a match.

He returned to his father's room and drew the curtains. The room became dark. He placed the candle on a small wooden table next to his father's bed and lit it. The light from the candle filled the entire room! (Adapted from Bachrach, 1966) Tesfaye is a good thinker. Cognitive psychologists might call him a good "information processor." What makes someone a good thinker or information processor? A precise answer to this question would require psychologists to examine someone like Tesfaye in the act of thinking and uncover the precise steps, mental structures, and processes involved in complex human thinking. Since these mental structures and processes cannot be observed directly, psychologists interested in the study of thinking use metaphors and models to explain what cannot be seen.

What are some of the metaphors and models that cognitive psychologists have created to explain what good thinkers do? First, they would say that good thinkers use *cognitive strategies*. An example of a cognitive strategy might be: "First try to picture or imagine the problem and picture or imagine several solutions." Undoubtedly Tesfaye did this when he scanned his father's room trying to visualize how a dollar's worth of anything could fill an entire room. Another strategy might be: "Don't jump to any conclusions. Test out what you think is the answer." Unlike his brothers, Tesfaye thought about the solution to the dilemma proposed by his father and visualized the solution before running out and purchasing the candle and match. There are many other cognitive strategies used by good thinkers to solve problems that you will learn about in this and the following chapter.

Cognitive psychologists also tell us that good thinkers are knowledgeable about and aware of their own thinking. They recognize when they are in a situation that demands the use of cognitive strategies. Good thinkers have cognitive strategies for finding out and organizing information and remembering when and where to use such strategies. In other words, good thinkers think about their own thinking.

Cognitive psychologists call this aspect of good thinking *metacognition*. If Tesfaye had thought to himself, "My father has challenged us with a real brain

teaser. I'll have to use some thinking strategies to solve this problem. What's one of the first things I should do?" he would be engaged in metacognition. In this chapter you will learn how good thinkers use metacognition to regulate, control, and monitor their use of cognitive strategies (Pressley, 1995).

Thus good thinkers possess strategies for thinking as well as for regulating the use of those strategies. In addition, good thinkers have a lot of information to draw upon to enrich their thinking. Each has a storehouse of facts, concepts, rules, principles, and other associations that are built up and organized from birth to adulthood.

Cognitive psychologists use a number of different metaphors to describe this storehouse of information: *knowledge base* (Bloom, 1985); *declarative knowledge* (Gagné, Yekovich, & Yekovich, 1993), and *domain-specific knowledge* (Chi, 1978; Chi, Glaser, & Farr, 1988). Good thinkers in the fields of science, classroom teaching, auto mechanics, chess, sports, or medical diagnosis all have extensive stores of organized information to draw upon. We're unsure what specific knowledge base Tesfaye drew upon to solve his father's riddle. But at a minimum, he needed to know what a dollar could and could not buy, how much space a dollar's worth of anything uses, and the difference between the area of a room and its volume. In this chapter you will learn what cognitive psychologists have discovered about the importance of using what you know to think effectively.

Good thinkers possess the ability not only to learn information and strategies, but also to recall this information on demand and coordinate the complex ways knowledge, strategies, and metacognition interact. Cognitive psychologists have created several models to explain the processes that good thinkers use in the act of problem solving. We will study several models of complex human cognitive functioning: the basic information processing model (Gagné, Yekovich, & Yekovich, 1993), and parallel distributed processing, or new *connectionist* models (Bechtel & Abrahamsen, 1991; Rumelhart, 1992).

By now you are probably asking yourself about the connection between good thinking and intelligence. After all, Tesfaye's father developed what he thought was a type of intelligence test—he wanted to find out which son was most intelligent. Is good thinking, or good information processing, synonymous with intelligence? In the final section of this chapter we will discuss the relationship between information processing and intelligence (Gardner, 1993; Sternberg, 1989).

As a teacher, one of your goals will be to help your learners become good thinkers. In Chapter 6 we will study the question of how to teach good thinking in the classroom. There we will learn what cognitive psychologists have discovered about the best ways to teach learners to be good thinkers. We will examine two categories of cognitive instructional methods: the earlier cognitive models of instruction that incorporate notions of discovery learning (Bruner, 1961) and meaningful verbal learning (Ausubel, 1968), and the most recent models based on social learning theory (Zimmerman, 1990) and social constructivist notions (Brown & Campione, 1986; Vygotsky, 1987).

# The Cognitive Approach to the Study of Learning

As you have gathered from our opening example and introduction, cognitive psychologists are concerned with studying good thinking—both the content of good thinking and its processes. You learned in Chapter 2 that good thinking requires that we find ways to represent in our minds those everyday events and actions we perceive through our senses. We called this "gaining freedom from stimulus control" and described cognitive development as the learner's gradual

accumulation of cognitive skills and abilities that allow her to think about both the real and the imaginary.

We cannot see good thinking. Nor can we see its content or its processes. As a result, cognitive psychologists use metaphors to describe what they cannot see or touch. Their metaphors are ways of talking about things too abstract to describe literally or precisely. When Forrest Gump says "Life is like a box of chocolates," he is using a metaphor to describe the intangible.

Cognitive scientists use a variety of metaphors to describe the content and processes of good thinking. They use these expressions not with the intent of stipulating what thinking actually is like, but with the goal of offering us a suggestion. They are saying, "Since you can't see or touch good thinking, why not think of it as a computer, or a filing system, or as an information management system." If thinking with the use of a metaphor is helpful to you, then the metaphor has value.

Almost all cognitive approaches to learning are concerned with how everyday experiences are transformed or processed into mental images or sounds and stored for later use. In other words, they are concerned with how information is processed. It is logical, therefore, that cognitive psychologists have chosen the information processing model or computer as their metaphor of choice.

Regardless of the metaphor chosen to describe good thinking or good information processing, all cognitive approaches to learning share certain basic ideas. These shared ideas, or basic elements of the cognitive approach, shown in Figure 5.1, are as follows:

Relevant learner characteristics Instructional manipulations Cognitive processes

BORICP05.doc - 8

# Cognitive outcomes

## Outcome performance

The cognitive approach to learning has a unique set of beliefs and assumptions about each of these elements. Figure 5.1 illustrates that cognitive psychologists are interested not only in what learners do at the end of a lesson (outcome performance), but also in the content of their thinking (cognitive outcomes), and in how this content is altered by the processes of thinking. Moreover, their research examines how characteristics of learners (such as memory capacity or cognitive development) and instructional manipulations (such as certain teaching practices) influence good thinking. In this chapter we will study what cognitive psychologists have learned about what makes good thinking and the cognitive processes involved in good information processing.

In the next chapter you will learn about those relevant learner characteristics and instructional manipulations that can help you teach good thinking. Before examining these elements of the cognitive approach, however, let's compare and contrast this approach with the behavioral approach to learning that we studied in the previous chapter.

# Differences Between the Cognitive

# and Behavioral Approaches

Cognitive approaches to learning differ from behavioral approaches in three respects: (1) types of learning examined; (2) research methodology; and (3) extent of human learning examined. As you will recall from the previous chapter, the behavioral science approach studies observable outcome performance (for example, right and wrong answers) and how to set up a learning environment to produce more correct answers than incorrect ones. It makes no assumptions about what or how learners are thinking while they are learning. Cognitive approaches to learning, as Figure 5.1 illustrates, emphasize good thinking or good information processing and the cognitive processes and outcomes that underlie right and wrong answers.

Cognitive approaches to learning examine human learning exclusively. They have no interest in animal learning, which is of prime concern to behavioral scientists. Consequently, cognitive psychologists use methods that allow them to infer what people are thinking. They give people complex learning tasks and measure variables like eye movements, eye fixations, time taken to react to a stimulus, self-reports of what the learner is thinking while engaged in the act of learning, or lists of pictures or words that the learner committed to memory and recalled (Gagné, Yekovich, & Yekovich, 1993; Solso, 1988). From these sources of data, cognitive psychologists make inferences about the content and processes of human thought.

Finally, cognitive psychologists limit their interest in learning to complex human thinking, such as concept and strategy learning, decision making, problem solving, and how learners construct knowledge. Unlike behavioral scientists, they do not study simple motor responses, right or wrong answers, or simple observable behaviors. Moreover, behavioral scientists have attempted to erect a system that can account for all human learning—behavioral, emotional, and social. Cognitive psychologists, in contrast, have limited their theorizing to those aspects of human functioning related to complex thought processes.

### The Content of Good Thinking

Good thinking involves three elements: strategies, metacognition, and knowledge. Expert thinkers in any field of study possess these three characteristics. As a teacher who is interested in teaching learners to be good thinkers, you will want to focus your lessons on these three areas. Let's examine what each contains.

## **Cognitive Strategies**

In the exercise below, fill in the blanks with terms that you have learned so far in this chapter, such as *information processing, good thinking, cognitive strategies, metacognition,* and *knowledge base.* Place your selections in the blanks in ways that make sense, but without trying to find the "best" or most correct answer.

alike? How are and What is the main idea of ? What are the strengths and weaknesses of ? In what way is ? related to How does affect ? What do you think causes ? What would happen if a learner were to use ? What do I still not understand about ?

King (1989) gave these generic questions to students in her undergraduate psychology class. She taught them how to use these questions in three different ways: (1) during class to learn more from her lectures, (2) after class to learn more from studying, and (3) as a basis for group discussion. She found that the use of these questions significantly improved what her students learned from her lessons.

If you use these questions on your own to learn what we are presenting in this text, you will have learned what cognitive psychologists call a cognitive learning strategy. **Cognitive strategies** are general methods of thinking that improve

learning across a variety of subject areas. Cognitive strategies go beyond the processes that are naturally required for carrying out a task (Pressley, Harris, & Marks, 1992). For example, as you read this paragraph you are engaged in decoding processes (moving eyes from left to right, instantly sounding out each word, and so on). Therefore, decoding is not a cognitive strategy, because it is naturally required, or obligatory, for reading. However, if before you began to read this chapter you scanned the headings and asked yourself questions about the chapter's subject matter, and if, as you were reading, you regularly paused and asked yourself if you understood what you were reading, then you would be using cognitive strategies.

Similarly, a student is not using a cognitive strategy when he regroups and borrows to solve a subtraction problem—he is doing what is naturally required to perform the task. However, if before solving the problem and during the act of problem solving, the learner prompted himself with statements such as "What am I supposed to do? What information am I given? First, I'll draw a picture of what the problem is asking," he would be using a cognitive strategy.

There are cognitive learning strategies to improve memory, reading comprehension, math problem solving, and problem solving in general. In the following sections, we will describe a number of strategies and demonstrate how you can use them in your classroom.

Strategies to Improve Memory. As we will see in our discussion of human memory processes, learners have only a limited capacity for recalling information. Permanent recall depends on how well the learner takes in new information and stores it. Cognitive psychologists have discovered a number of strategies for improving memory that you can teach to your students. These strategies typically involve rehearsal, elaboration, and organization. **Rehearsal** involves repeating to yourself what you are reading or hearing. This could involve repeating the lines in a poem, letters that spell a word, or a list of steps to be followed.

School-age learners are expected to learn the names of letters, associate sounds with particular letters and letter combinations, and memorize addition, subtraction, and multiplication steps, facts, dates, scientific terminology, and word definitions. Learners who experience difficulty memorizing such information are often helped by learning a memory strategy called **elaboration**. Learners use elaboration when they associate a particular image with something they are learning (for example, a learner recalls an image of an apple to learn the sound of the letter "a"). They might also relate something they have already learned to new material. Van Houten (1994) taught letter sounds and multiplication facts to learning disabled students using an elaboration technique that he calls *color mediation*. A child who has learned to label several colors correctly is taught to apply color labels to letters or number facts printed in a particular color (for example, red is associated with "9," or green with "p"). The number or letter in question is printed in the color associated with its verbal label. The child learns to label the letter or recall the number fact by matching it with its color.

The **keyword method** (Levin, 1985) is an elaboration strategy in which the learner transforms one or two related pieces of information into a "keyword" already familiar to her. For example, students in high school are often required to learn foreign language words and definitions. The students have two pieces of information to associate—one of which is an unfamiliar term (the foreign word). The foreign word can be transformed into something familiar, thus making its definition easier to remember. For example, to learn that *pollo* means "chicken" in Spanish, a learner would identify a word that looks or sounds like *pollo*. Either "pole" or "polo" could serve as a keyword for *pollo*. Thus the learner might

imagine a chicken scratching the ground at the North Pole or a team of chickens playing polo. The potency of this memory strategy has been demonstrated in scores of studies used with learners from elementary school through college (Pressley, 1995).

**Organization** is a term applied to memory strategies in which the learner groups or arranges the information being studied according to some system. *Chunking* is an organization strategy in which the learner places information in related groups. Another organization strategy is to arrange information into some type of outline form with headings and subheadings. The accompanying box, *Teaching Memory Strategies,* contains additional examples of memory strategies. Teaching students to employ such mental organizers gives them creative alternatives by which to manipulate ideas and information, retain mental strategies for learning, and thus internally reinforce their own learning.

Strategies to Improve Reading Comprehension. The goal of reading instruction is to train learners not how to say words but how to get meaning out of them. **Comprehension monitoring** is a term applied to a host of strategies learners can use to derive meaning from what they read. Specific examples of comprehension strategies include *Survey, Question, Read, Recite, Review* (SQ3R) (Robinson, 1946); its somewhat more recent variation, *Preview, Question, Read, Reflect, Recite, Review* (PQ4R) (Thomas & Robinson, 1972); and *question generation* (Rosenshine & Chapman, 1992). These comprehension strategies have in common the following skills:

1. *Setting goals for reading:* Learners learn to ask themselves "What do I have to do?" and "Why am I reading this story?"

- 2. *Focusing attention:* Learners learn to prompt themselves with questions such as "What am I supposed to do as I read?"
- 3. *Self-reinforcement:* Learners learn to say to themselves "Great, I understand this. Keep up the good work," or "This strategy really works."
- 4. *Coping with problems:* When they encounter difficulties, learners learn to say to themselves "I don't understand this. I should go back and read it again," or "That's a simple mistake. I can correct that."

The accompanying box, *Using Reading Comprehension Strategies*, describes several other strategies that teachers of any subject area can teach to learners at the elementary or secondary school level.

Strategies for General Problem Solving. Many systems for problem solving can be taught to learners (Pressley, 1995). There are problem-solving strategies to improve general problem solving (Burkell, Schneider, & Pressley, 1990; Mayer, 1987; Sternberg, 1988), scientific thinking (Kuhn, 1989), mathematical problem solving (Schoenfeld, 1989), and writing during the elementary years (Harris & Graham, 1992a) and during adolescence (Applebee, 1984; Langer & Applebee, 1987).

A problem-solving system that can be used in a variety of curriculum areas and with a variety of problems is called IDEAL (Bransford & Steen, 1984). IDEAL involves five stages of problem solving:

1. Identify the problem. Learners must know what the problem is before they can solve it. During this stage of problem solving, learners ask themselves whether they understand what the problem is and whether they have stated it clearly.

- 2. **D**efine terms. During this stage, learners check whether they understand what each word in the problem statement means.
- 3. Explore strategies. At this stage, learners compile relevant information and try out strategies to solve the problem. This can involve drawing diagrams, working backward to solve a mathematical or reading comprehension problem, or breaking complex problems into manageable units.
- 4. Act on the strategy. Once learners have explored a variety of strategies, they select one and now use it.
- Look at the effects. During the final stage of the IDEAL method, learners ask themselves whether they have come up with an acceptable solution.

The accompanying box, *Using the IDEAL Method*, provides a sample dialogue to show how a fifth-grade teacher taught her learners to use IDEAL.

Summary. There is abundant evidence that learners as young as 2 years use problem-solving strategies. Good learners at all grade levels know and use strategies to accomplish school tasks in reading, math, science, and social studies. They know how to use memory strategies to improve recall, comprehension strategies to learn more from reading, and general problem-solving strategies to improve math and science understanding. In the next section we will present research on how learners learn *when* to use cognitive strategies—an important aspect of good thinking called *metacognition*.

# Metacognition

Pressley, Borkowski, and O'Sullivan (1984, 1985) reviewed a series of experiments that demonstrate that knowing how to use a cognitive strategy is no

guarantee that learners will use it when they need to. In these experiments, one group of learners was taught a strategy for a particular task. A second group was taught the same strategy for the same task but was also told that using the strategy would increase learning. As predicted, learners who were informed about the usefulness of the strategy were more likely to use and remember it than those who were not informed.

O'Sullivan and Pressley (1984) found that groups of children who were given information on when and where to use a strategy for which they were trained used that strategy on a greater variety of tasks than those not given such information. From this research and that of others (Meichenbaum, 1977; Weed, Ryan, & Day, 1990), we know that the long-term use of strategies by your learners depends on how well you supplement the teaching of strategies with instruction on when and where to use them. Students who are aware of when to use strategies are said to possess **metacognition**—or knowledge about their cognition.

Development of Metacognition. While children as young as 2 years use cognitive strategies, they are not aware that they are using them and thus do not do so intentionally. The capacity to think metacognitively appears to develop as children enter the concrete operational stage of development (ages 5 to 7). Nevertheless, learners who use strategies typically fail to notice that the strategy is helping them, and often fail to use it when the opportunity arises (Pressley, 1995).

Ghatala (1986), Ghatala, Levin, Pressley, and Goodwin (1986), and Pressley and Ghatala (1990) conducted a series of studies on metacognition with school-age learners. They taught fifth- and sixth-grade learners two strategies for learning vocabulary words, one of which was clearly more effective than the others. To their surprise, the learners did not notice that one was more effective. Only when this was pointed out did the learners choose the more effective strategy for subsequent vocabulary-learning tasks.

The surprising conclusion from this research is that learners in second through sixth grades do not automatically acquire metacognitive knowledge. In other words, while engaged in using strategies, they don't automatically realize that one strategy may be better than another, spontaneously compare the effectiveness of the strategies, or use information about the effective use of the strategy to make future decisions. Learners at this age can learn to make these decisions, but they need explicit instruction.

Teaching Metacognition. The work of Ghatala and Pressley on the development of metacognition in young children makes two main points: (1) learners as young as second grade can learn to regulate their use of cognitive strategies, but (2) they require systematic instruction to do so.

Thus, if you want your learners to use cognitive strategies to improve their learning of vocabulary, spelling, number facts, reading comprehension, or problem solving, you must not only teach these strategies systematically, but also teach learners to regulate their use. Metacognitive instruction involves teaching your learners to: (1) attend to the effectiveness of strategies, (2) attribute differences to the relative effectiveness of a particular strategy, and (3) use the more effective strategy in future decision making (Ghatala, 1986). Otherwise, learners may not use a given strategy, not notice whether it is effective, or fail to use it when they should. The accompanying box, *Teaching Metacognitive Knowledge*, provides some specific guidelines for teaching metacognition.

Summary. Learners who are taught cognitive strategies are not aware of the effect of the strategy on their learning unless they have the opportunity to compare their performances when they do and do not use the strategy. Metacognitive knowledge must go hand in hand with instruction if learners are to use strategies to improve their thinking.

As we showed in the introduction to this chapter, good thinkers not only know cognitive strategies and regulate their use, they also have knowledge of the area they are thinking about. It is to this important topic that we turn next.

#### Knowledge

If you plan to teach history, social studies, science, literature, or the cultural arts to children in elementary, junior, or senior high school, you have probably asked yourself the following questions: Is it really important that my learners have a lot of factual information about the subject I'm teaching? What difference does a knowledge of important facts, concepts, and principles in my field make in my learners' ability to think? What can a learner with a large amount of knowledge do that a learner with limited knowledge can't? As you will see from the next section, the answer is: A lot.

The Effect of Knowledge on Learning. Suppose you gave the same memory task to two groups of learners—fourth graders and twelfth graders. If the memory task involved recalling specific information from the sports page of a daily newspaper, which group would remember more? Make your choice before reading on.

Now suppose we were to tell you that the fourth graders were all sports buffs and that the twelfth graders didn't know the sports page from the society column. Now who would you predict would remember the most from the memory task? If you predicted the fourth graders, you are most likely correct.

Let's change the task. Suppose the memory task involved recalling the names of pictures of 20 common objects including a bike, a car, a ring, and a hairbrush that the learners saw for 60 seconds. Who would recall more? Here the older learners would do better. Why? The answer has to do with the role of knowledge. In the first example, the fourth graders have specific knowledge about sports. Therefore, when they read the sports page they understand and recall much more than the twelfth graders, who are unfamiliar with such terms as zone defense, nickle defense, the blue line, sacrifice, infield fly rule, and point guard.

The fourth graders possess what cognitive psychologists call **domain-specific knowledge**, or knowledge of facts, concepts, and principles pertaining to a specific

area or topic (for example, the Civil War, chess, how an engine works, cosmetology). Domain-specific knowledge is different from **general knowledge**, which is knowledge useful for learning across a variety of school tasks. Examples of general knowledge are how to write or spell, how to use a dictionary or encyclopedia, and how to use a computer. Domain-specific knowledge allows the fourth-graders to think about and process information about their domain of expertise better than learners who are unfamiliar with the domain (Chi, 1978). General knowledge, however, allows the twelfth-graders to do a better job of recognizing familiar objects.

Here's another demonstration of the importance of a knowledge base in learning. Schneider, Korkel, and Weinert (1989) and Schneider and Korkel (1989) asked 8-, 10-, and 12-year-old children to read passages about soccer, a sport popular in Germany, where they conducted their research. After reading the passages, the children were asked questions that assessed recall of specific information, the making of inferences, and detection of contradictions. Some of the children across all age levels knew a lot about soccer, some very little. In addition to measuring the soccer expertise of the children, the researchers also measured their general intelligence by means of an IQ test. The researchers found that age had a lot to do with performance on the reading tests—12-year-olds made more correct inferences than 8-year-olds, as you would expect. But they also found that prior knowledge of soccer was associated with higher learning, regardless of age level. Knowledgeable 8-year-olds did better on the tests than did novice 12-year-olds. Even more striking was the fact that general intelligence was not a strong determinant of performance. Learners with a lot of soccer expertise and average general intelligence outperformed novice learners with high general intelligence.

These results have been confirmed in this country with both children and adult learners. Walker (1987) found that baseball experts with low general intelligence learn more from a baseball passage than do baseball novices with high general intelligence. Ceci and Liker (1986) went to a racetrack and located both experts and novices at race handicapping who were comparable in years of education, years going to the track, and job prestige. The range of IQ in both groups was from 80 to 130. The task given to the subjects was to handicap 50 two-horse races. They were given a variety of statistics and asked to compute the odds for each of 50 races that pitted an unnamed horse against a horse that was the same in each race. The researchers found that the complexity of the reasoning of the low-IQ experts was far greater than that of the high-IQ novices.

Thus, domain-specific knowledge appears to be much more important in determining good thinking and performance on a given task than general intelligence. The message for teachers who want to teach their learners to be good thinkers is clear: Teaching cognitive strategies and metacognitive knowledge is necessary for good thinking, but it is not sufficient. You must also ensure that your learners have mastered the critical information in the area in which you want them to think well.

Types of Expert Knowledge. What types of knowledge do experts have that allow them to think so productively? Cognitive psychologists have classified knowledge in a variety of ways. We have already discussed one such type: domain-specific versus general knowledge. Another way of categorizing knowledge is declarative knowledge versus procedural knowledge. **Declarative knowledge** is another name for verbal information: the facts, concepts, principles, and theories that we learn from lectures, studying textbooks, or watching television. **Procedural knowledge** is know-how: knowledge of the action sequences involved in booting a floppy disk, writing an outline, tying your shoes, focusing a microscope, or playing a trombone. To give you a better feel for the distinction between declarative and procedural knowledge let's examine what researchers have found about the knowledge bases of expert teachers (Berliner, 1986, 1988; Carter et al., 1987, 1988; Peterson & Comeaux, 1987).

Researchers in teaching expertise typically ask experienced and beginning teachers to view videotapes of real-life classroom episodes and to then make judgments about what is happening in the classroom. The teachers record their judgments on tape or write them down. Researchers then analyze these tapes for what they reveal about the knowledge bases of expert and novice teachers. What they find is that expert teachers are able to classify the types of instruction and activities they view (discovery learning, lecture, discussion, and so forth), relate the activities of the lesson

to the behavior of the learners, categorize the behavior of the learners (attentionseeking, power struggle, and so on), and suggest alternative courses of action. Novice teachers, on the other hand, have little understanding of what is going on in the classroom, see few connections between teacher behavior and learner behavior, and have few suggestions. In short, expert teachers possess a great deal of declarative knowledge about specific subject area teaching practices, curriculum materials, the characteristics and cultural backgrounds of learners, theories of instruction, and theories of learner behavior (Shulman, 1987) that allows them to make sense out of what they see in classrooms.

Other researchers who have studied the procedural knowledge of expert teachers (Calderhead & Robson, 1991; Elbaz, 1983; Emmer et al., 1994; Leinhardt & Greeno, 1986) have shown that expert teachers draw up extensive lesson plans, know how to prevent behavior problems from escalating, monitor students as they are learning, develop efficient techniques for grading papers and giving students immediate feedback on learning, and know how to ask questions that elicit reflective comments by students.

Characteristics of an Expert's Knowledge Base. So far we have learned that experts in any area have a large base of knowledge that includes both declarative and procedural knowledge. This knowledge base allows experts not only to think well, but also to think quickly. Experts are fast: they solve problems faster than novices and with fewer mistakes.

One reason they solve problems faster is because their procedural knowledge is automatic—a characteristic of the knowledge base often referred to as **automaticity** (Sternberg, 1989). Automaticity means that a procedure has been learned so thoroughly that it is carried out with little thinking and little effort. Good readers decode automatically—they don't have to think about sound/symbol associations. Good writers construct sentences automatically—they don't have to think about grammatical rules as they are writing. Expert problem solvers in math perform math operations automatically—they don't spend a lot of time thinking about how to regroup in subtraction, carry in addition, or find the least common denominator when working with fractions. Experts also think quickly because their declarative knowledge base has *organization*. As we discussed earlier in this chapter, organization means that the declarative knowledge in a particular domain is connected and related. Early cognitive psychologists like Bruner (1966) and Ausubel (1968), as well as current researchers (Bjorklund, 1989; Rabinowitz & McCauley, 1990), speculate that as the expert's knowledge base grows, it becomes increasingly organized and related.

This organization of information is often *hierarchical:* for example, the mind organizes the information in a specific area, such as "earthquakes," from the most general principles to the most specific details. In other words, general principles of plate tectonics (geologic activity occurs where plates converge) subsume concepts (pressure, crust, tectonic plates), which, in turn, subsume specific facts (location of plates, mountain ranges, number of continents). According to these researchers, it isn't simple cognitive strategies that allow experts to reason and solve problems quickly. Rather, it is the organized nature of the information base that allows the learner to quickly access information and use it to expertly perform a task.

Educational Implications. As the saying goes, "Knowledge is power." A knowledgeable learner with an average IQ is a better thinker in a given area than is a learner with a high IQ who lacks domain-specific knowledge. Therefore, the message for teachers who want their learners to be good thinkers is clear: Teach important declarative and procedural knowledge. Make sure that you help your learners organize and categorize the verbal information so they can access it from memory quickly and efficiently. In addition, provide extensive practice with procedural knowledge so learners can perform operations like decoding text, writing sentences, or carrying out basic math procedures automatically and effortlessly.

Concluding Comments. Cognitive psychologists tell us that good thinkers or good information processors in any area of expertise have (1) an extensive knowledge base, characterized by (2) organization, and (3) automaticity. They use cognitive strategies when thinking and know when and where to use these strategies. The expert teach-

ing of good thinking requires that teachers attend to all three components of good thinking.

But how do learners come to learn, retain, and use these processes? Cognitive psychologists can't see the processes of good thinking at work. So to help understand them, they use models. In the next section, we will examine the most popular of these models—the information processing model—and study some of its more recent variations.

# The Information Processing Model

In the preceding section, we learned what makes good thinking. By now you are probably asking yourself "What is the best way to teach strategies, metacognition, and knowledge to my learners?" This is also a goal of cognitive psychologists—designing instruction to make learners better thinkers. However, cognitive psychologists realize that another question must be answered before we can answer the question of how good thinking can be taught. This question is: "What does good thinking look like?"

Cognitive psychologists have some ideas about what makes up good thinking. These components were the subject of the preceding sections of this chapter. But how do knowledge, cognitive strategies, and knowledge about the use of cognitive strategies get into our heads in the first place? And once this content gets there, what happens to it? How does it get organized and sorted? Where exactly is the information stored? How is it retrieved?

All these questions have to do with how the mind works—the processes involved in good thinking. Accurate answers to these questions would greatly help us in our efforts to teach learners to think better. For example, knowing how the mind takes in new information would allow you to make better decisions about how to present new information. Knowing how the mind categorizes or organizes this information would allow you to present new information in the most efficient way.

In this section you will learn what cognitive psychologists know about how the mind takes in information, and what the mind does with that information once it has gotten in. We will examine in depth the **information processing model** to understand what it says about the flow of information into the mind. We will also discuss the **parallel distributed processing** (PDP) or *new connectionist* **model**, a model that reflects the latest hypotheses about how the mind works.

The information processing model seeks to describe what happens to information the first time it is presented to a learner. For example, the first time a ninth-grade biology student hears about the structure of the circulatory system, what happens to all the related facts, concepts, and principles? How is the biology information processed? The model shown in Figure 5.2 is a general metaphor for information flow that applies to any situation in which the mind receives new information. In this figure we see five rectangles labeled "receptors," "effectors," "immediate memory," "working memory," and "long-term memory." These boxes represent different functions, or processes, that are activated as information is being processed. They do not correspond to physical locations in the brain; they represent only functions. Arrows in the model represent the sequence in which these functions occur, while ovals stand for control processes or executive routines that govern or regulate information flow. Control processes include goal setting, strategy selection, expectations, monitoring progress, and metacognition (when we consciously regulate control processes).

# **Reception of Information**

Information processing begins when the learner starts reading an assigned history chapter, watching a science demonstration, or listening to the explanation of the legislative process in a political science class. *Receptors* (such as rods and cones in the eyes, bones in the middle ears) take in light and sound energy, transform these different energy forms into electrical impulses, and send the impulses to the brain. These impulses are registered in **immediate memory** (IM). IM holds this wealth of sensory information for the briefest period of time—Sperling (1960) estimates a visual stimulus decays in about a fourth of a second. Nevertheless, these impulses linger just long enough for the control processes involved in selective perception to impose some organization or meaning on them. Thus, not all information coming into IM is lost.

Selective perception occurs when the learner attends to what is most important in the information coming in through the receptors and attaches some meaning to it. When the stimulus itself provides the meaning, *bottom-up processing* is said to occur (Gagné, Yekovich, & Yekovich, 1993). In other words, when the light patterns from a motorcycle are received on the rods and cones, your mind analyzes the patterns and instantly recognizes it as a motorcycle—something that has meaning to you. But we also selectively perceive through *top-down processing*. For example, when a learner is reading a history assignment dealing with the Protestant Reformation, she will more quickly recognize the word "schism" because she already possesses *prior information* about schisms and has certain *expectations* for what the homework is about. Thus, selective perception, whether top-down or bottom-up, is influenced by visual, auditory, or tactile stimulus patterns, prior knowledge, and expectations.

*Attention* also has a great deal to do with selective perception. It is particularly important during the early stage of processing unfamiliar information. Attention maintains the learner's vigilance, which keeps the selective perception process going and enhances sensory acuity, which in turn makes one aware of new stimulus cues. Thus, gaining and holding a learner's attention, particularly at the beginning stages of a lesson, is a pivotal challenge to teachers. The accompanying box, *Grabbing and Holding Your Learners' Attention*, provides specific suggestions.

#### Working Memory

**Working memory** is often referred to as *short-term memory*, although there are some subtle differences between the two concepts. Pressley (1995) refers to both working memory and short-term memory as "attentional capacity." If the learner attends to and selectively perceives the data that enter immediate memory (IM), these data next enter working memory (WM). Try to picture the function of WM in terms of awareness. What you are aware you are thinking about at any given moment is said to be in your WM (Gagné, Yekovich, & Yekovich, 1993). WM is of limited duration—current research suggests that it retains new information for about 10 to 20 seconds. After that, the information is either lost or transformed.

For example, we've all had the experience of getting a number from the telephone operator but having no pencil to write it down. The number gets into WM, but it is quickly lost unless you either write it down or repeat it a few times (a process called *rehearsal*). This is an example of the limited capacity of WM. Estimates are that its capacity is limited to five to nine isolated bits of information—in this example, numbers (Miller, 1956).

WM is where conscious thinking occurs—consider it a kind of mental workplace. When you try to solve a math problem in your head (for example, "If pencils cost 69 cents a dozen, how much will nine pencils cost?") you are using your WM. Because of its limited capacity and duration, WM is not a good place to perform several different mental operations at the same time. Try comprehending the main point of a sentence you are reading in a foreign language when at the same time you have to sound out and then think about the meaning of half the words. Reading comprehension occurs in working memory, which is why learners who are slow in word decoding are also weak in comprehension.

Why We Forget. Information in WM is quickly forgotten unless the learner attempts to prolong its stay. This can be done by using memory strategies of the type we referred to in the earlier box on teaching memory strategies.

Several theories try to explain why WM is of such limited duration and capacity. **Decay theory** holds that information simply leeches out of WM or dissolves. The energy impulses dissipate with the passage of time unless we rehearse the new information. While decay theory presents some vivid metaphors, it is not as convincing as displacement theory. **Displacement theory** (Miller, 1956) suggests that there are only so many "slots" in WM that can be filled. Once new information comes into WM, the existing information is pushed out and replaced by the incoming data. Displacement theory is closely related to **interference theory** (Ausubel, 1968), which posits that subsequent learning competes with prior learning and somehow interferes with what's contained in WM.

Information in WM is like information in the working memory of your computer. If you want to save it, you must transfer it to a long-term storage device. WM helps process information into a form that is acceptable for more permanent storage in long-term memory—like saving a document on the hard drive in your computer.

Implications for Teaching. The function of WM has important implications for your teaching. Two of these implications are as follows:

- 1. Unrelated facts are quickly forgotten unless the learner organizes them in some way or unless you help the learner to do so (remember that different learners have different storage capacities in WM).
- 2. The more you allow learners to think about information in WM, the more likely they are to put that information into more permanent storage. Active processing or thinking about new information, such as taking notes, discussion, and practice, are essential learning strategies for accomplishing this.

# Long-Term Memory

Information from WM may be stored in **long-term memory** (LTM). Storage is a term or metaphor that describes a series of processes whereby new information is integrated with information that is already known or residing in LTM. The principal storage processes, as you have already learned, involve rehearsal, elaboration, and organization.

The Form of Knowledge in LTM. There is considerable discussion among cognitive psychologists about what exactly is stored in long-term memory. At one level, we know that declarative and procedural knowledge are stored there. But what form does this information take in long-term memory? This is an important question, because if we know in what form information is stored in LTM, we could present information to learners in that form to facilitate remembering. For example, if information is stored in long-term memory in the form of visual images, then teachers could help their learners to encode information visually. Cognitive psychologists propose a number of theories about how knowledge is represented in LTM: dual-coding theory, propositional networks, and schemas.

"Don't think about pink elephants." As soon as you hear this, what do you do? If you're like most people, you think about pink elephants. In thinking about *how* we think, we all depend on images to help us. We also depend on words, particularly when we can't construct an image (for example, try to imagine a heffalump). Paivio (1971, 1986) has developed a **dual-coding theory** of long-term storage. He believes that information in LTM is composed of complex networks of verbal representations and images. A good example of the verbal imaging of information is when you think about the concept "dental cavity." Your experience probably includes images of drills, excruciating pain, needles, chairs, and New Age music.

In addition to verbal images, however, you also think in terms of connected ideas (for example, "If A is bigger than B, and B is bigger than C, then A is bigger than C"). Anderson (1983) proposes that much declarative knowledge is stored in LTM in the form of extensive networks of interconnected ideas called **propositional networks.** Figure 5.3 illustrates one such network, a set of propositions about Benjamin Franklin. Cognitive psychologists propose that if we could see into a learner's brain and examine those neurons that contain information about Benjamin Franklin, it would look something like this web of ideas, concepts, and facts. If LTM actually stores information in the form of propositional networks, teaching learners how to outline and make connections during a lesson would greatly facilitate remembering.

A third hypothesis about the form of information in LTM is called **schema theory** (Anderson & Pearson, 1984). You are familiar with the concept of *schema* 

from Chapter 2. Recall that cognitive schemata are integrated units of knowledge. They are cognitive structures that organize large amounts of information about objects (the Taj Mahal), events (the first landing on the moon), or text readings (Willa Cather's *The Lost Lady*). Your learners have schemata for "a birthday party," "the first day of school," "the senior prom," and so forth, which organize a vast array of information about events, people, feelings, and their relationships. These schemata influence how learners perceive and make sense of what they hear and read.

Capacity of LTM. Most cognitive psychologists stipulate that information in LTM lasts a lifetime (Gagné, Yekovich, & Yekovich, 1993). Then, you may be asking yourselves, how come we forget so much? Cognitive psychologists believe that your experience of forgetting things you once "knew" is due more to your failure to find a good way to retrieve the information than to any permanent loss of data.

A good example of the permanence of LTM comes from a study by Williams and Hollan (1981). They asked people who had graduated from high school between 4 and 19 years earlier to recall as many names of individuals as possible from their high school classes. At first the subjects were slow to come up with names. But as they began to use clues, such as "the kids who lived on my block," "the kids I rode to school with," or "the kids in my physics class," recall dramatically improved. The subjects in the study recalled large percentages of their graduating classes despite the fact that these classes were quite large.

Retrieval Processes. As this example shows, when we actively search our memories for information to use in a thinking task (to get it into working memory) we are engaged in *retrieval processes*. Cognitive psychologists use the term *activation* to refer to cognitive processes involved in becoming aware of what we have learned and in establishing connections between this prior learning

and the task in which we are currently involved. This connection-building is facilitated by the use of retrieval cues.

*Retrieval cues* are hints or things we say to ourselves to help us remember what we have already learned and stored in LTM. In the experiment about remembering one's high school classmates reported above, retrieval cues were the hints, such as "the kids who lived on my block." Retrieval cues are particularly effective when the cue you are using to recall information matches information that you stored at the time of original learning. For example, the cue "who are the kids in my physics class?" would be of no help if, at the time you were taking high school physics, you never noticed who was in your class.

Tulving (1989) believes that good recall of memorized information is largely cue-dependent. You forget the meaning of a word that you once knew, such as *homunculus*, because you don't have a cue that emphasizes remembering it. You forget how to spell a particular word because you fail to use a cue that emphasizes sound. Depending on the type of recall you want (meaning, spelling, date, name, address, phone number), there are cues to match it.

# Implications for Teaching

The information processing model of how the mind works is a metaphor. In this chapter, we used it to help you think about how the minds of your learners work. This model can help you think about what you can do during your lessons to help your learners better understand and retain what you are teaching.

During our discussion we highlighted various models of how information gets into the mind, how it is stored, and how it is retrieved for use in thinking. According to the information processing model, there are three conditions for meaningful learning: the cognitive processes of reception, availability, and activation. Figure 5.4 illustrates how these three conditions work together to result in meaningful learning, and the accompanying box, *Using the Information Processing Model to Promote Learning*, suggests specific strategies you can use to establish these conditions in your classroom.

#### The Parallel Distributed Processing Model

Cognitive psychologists have only just begun to understand how the mind works. The information processing model has contributed greatly to the development of the cognitive science of learning. Nevertheless, alternative models of the architecture of the mind reflect both the latest advances in computer science and our understanding of cognitive processes.

McClelland and Rumelhart (1981, 1986) believe that the information processing model encourages a perspective on thinking that is inconsistent with our experience. According to the information processing model, the mind is a system that performs one action after another very rapidly (reception followed by flow into working memory followed by storage into long-term memory followed by retrieval and transfer to working memory, and so on).

Rumelhart's view (1992), on the other hand, is that the mind does a lot of things not one at a time, but rather all at once, much like the various processing units of a powerful computer. Inside a computer are complex arrangements of memory chips, processors, disks, switches, and drives. These components don't perform complex operations in an orderly, sequential fashion. Rather, they do a lot of things simultaneously as they solve problems.

So, too, the brain is made up of complex collections or arrangements of neurons that form *neural networks*. The brain contains many neural networks that perform a variety of specialized functions involved in complex thinking. There are neural networks for decoding text, solving arithmetic word problems, playing chess, and so forth. These networks are made up of smaller units, called *nodes*,

that contain particular types of information (words, letters, sounds, images, rules) important to completing the task of the network.

No central processor or organizer (like the ovals in the information processing model in Figure 5.2) governs how these nodes work together. Instead, the nodes are simultaneously active—they activate one another; they build new connections among one another; and eventually they learn and solve the problem at hand.

As a specific example of a neural network model, Gagné, Yekovich, and Yekovich (1993) considered Marshall's work (1990) on how students distinguish among five types of arithmetic word problems. Marshall studied the five types of word problems exemplified in Table 5.1. *Change* problems are characterized by a change in the state of one quantity. *Group* problems involve situations in which two or more groups can be logically combined into a larger group. *Compare* problems contrast the values associated with two objects. *Restate* problems require rephrasing a verbal description into a different set of quantitative terms. Finally, *vary* problems depict direct or indirect variation.

Marshall postulated that through practice and feedback in identifying these five kinds of problems, students begin to form "pattern-recognition" units that fit specific problem types. Certain features of the word problems are associated with certain types of problems. For example, phrases like "how much bigger" or "how much more" are almost always associated with "compare" problems. Thus, these phrases come to be part of the pattern-recognition unit for such problems. These units are said to exist in long-term memory.

After learning, when a student reads a new problem, he represents its features in working memory. These features then activate the same features coded in longterm memory, and the features coded in long-term memory start to activate the pattern-recognition unit to which they belong. Figure 5.5 shows what happens when a student reads a new word problem. The arrows at the bottom of the figure represent input from the environment (the printed problem statement). The large circle represents working memory, and the elements within this circle represent features and pattern-recognition units stored in long-term memory. Notice that elements of three different problem types (change, compare, and restate) have been activated by their connections to the representation of the current problem.

How does the learner decide which of these problem types best fits the current problem? Usually, more features of one pattern-recognition unit are activated than of any other. The unit with the most activated features is selected as appropriate. In the example in Figure 5.5, the "compare" unit has four features activated, versus only two and three for the "change" and "restate," respectively. Note that according to this model, the pattern recognition units are activated *simultaneously*. This is a characteristic assumption of neural network models.

As you can see, this model involves a great deal of metaphorical thinking, which can make the model difficult to understand and apply. However, your own experience of thinking and problem solving may help: when engaged in problem solving, you are aware of many things at once: ideas, images, facts, rules, principles, and sounds pop in and out of your consciousness, and eventually some closure comes about. This kind of experience suggests that the PDP model is a valid metaphor for human thought.

# **Teaching Implications**

The neural network models of cognitive functioning suggest that the minds of your learners may not always work in orderly, sequential ways. Your learners may figure things out without being given an orderly set of rules for doing so. They may not always think rationally and logically as they are solving problems. They may construct their own meanings or make their own sense of things without

BORICP05.doc - 36

considering all the facts, advantages and disadvantages, similarities and differences.

The PDP model reminds you that thinking is not simple and orderly, based on neatly stored knowledge. Rather, a lot of thinking goes on at the same time the learner is gathering new knowledge and pondering over ongoing situations. PDP theorists believe that learning depends largely on the interactions between what is in the learner's head and what is outside it. Consequently, many of the constructivist teaching approaches we will study in the next chapter have their conceptual roots in the PDP approach to cognitive processing.

# Cognitive Approaches to Learning and Intelligence

One of the goals of understanding how the mind works is to develop instructional methods that teachers can use to help learners become better thinkers. This goal inevitably raises the question: "If we can teach learners to think better, can we teach them to be more intelligent?" In other words, when we use the expression "good thinking" or "good information processing," do we really mean "good intelligence"? What is the difference between intelligence and the cognitive processes of good thinking? To answer this question we will examine the work of two psychologists who view intelligence from a cognitive processing perspective: Howard Gardner (1983, 1991, 1993) and Robert Sternberg (1989, 1994, 1995).

## Views of Intelligence

There are two major views of intelligence. The *classical tradition* attempts to understand the content, or *structure*, of intelligence, while the *revisionist tradition* seeks to understand its *processes*. Although we will return to the topic of

intelligence in Chapter 11, let's briefly describe the former tradition and, then, because of its relevance to how the mind actually works, focus on the latter.

Intelligence as Structure. For most of the twentieth century, psychologists studying human intelligence have created tests to help them understand the underlying abilities that make up intelligence (Jensen, 1980). They asked questions such as "Is intelligence one *general* ability or many *specific* abilities (e.g., spatial ability, verbal ability, quantitative ability, etc.)?" These psychologists agree on several points:

- 1. Tests that contain questions to which there are clearly right and wrong answers are the best way to learn about intelligence.
- 2. The ability that underlies intelligence (in other words, the structure of intelligence) exists within the person and is largely inherited.
- 3. Intelligence is largely neurophysiological, involving such factors as the speed of transmission of nerve impulses.
- 4. Intelligence cannot be significantly improved through instruction or training.

Intelligence as Process. Rather than seek to understand the content or elements of intelligence, other psychologists have sought to understand what people do when they are engaged in intelligent behavior. Largely influenced by cognitive psychology, these psychologists view intelligence from an information processing framework. For them, what is important is the way in which people combine knowledge, strategies, and metacognitive processes to solve problems important to them. These theorists also share a common set of beliefs.

- 1. Intelligence may have a structure (abilities, and so on), but what's more important in studying and describing it is an understanding of its underlying processes.
- 2. Intelligence can be significantly improved by education and training.
- 3. Standardized tests are not the best way to explore the nature of intelligence. Instead, the best way to measure intelligence is to have people solve problems that are culturally relevant and to then examine the processes they used to do so.
- 4. There is a genetic component to intelligence, but it does not account for the majority of intelligent behavior.
- 5. Intelligence is strongly influenced by one's cultural environment. The study of intelligence must take into consideration the different environments to which people must adapt.

Two of the most prominent theorists of intelligence who work within the information processing tradition are Gardner and Sternberg. In the next sections, we will describe their recent work and discuss its relevance to classroom teaching.

## Gardner's Theory of Multiple Intelligences

For Gardner (1993), intelligence involves the ability to solve problems or fashion products (compose music, write poems, choreograph a dance) that are of consequence in a particular culture or community. He rejects the notion that we can learn about intelligence by studying how people answer questions on tests. For Gardner, we can only learn about intelligence by studying the cognitive processes people use when they are solving important cultural problems or creating important cultural products. Gardner has identified seven intelligences that are involved in solving problems and fashioning products, and he believes that all seven can be taught in school. He has also developed a curriculum to do so, called Project Spectrum (Gardner, 1993). Table 5.2 describes the seven intelligences, and Table 5.3 shows how Gardner has translated these into a school instructional program.

For Gardner, problem solving is essential to intelligence. This is consistent with many traditional notions of intelligence. However, Gardner insists that problem solving can be studied only by observing people solving problems or creating products that are important to them, not by administering standardized tests.

Gardner believes that by observing people solving the naturalistic, culturally important problems his seven intelligences represent, we will eventually map out the cognitive processes involved in good thinking. But he also predicts that no single model of cognitive functioning will be found to underlie all human problem solving. Rather, cognitive processes vary depending on the task a learner is involved in.

## Sternberg's Triarchic Theory of Intelligence

Sternberg (1989, 1994) agrees with Gardner that the best way to study intelligence is to examine how people solve the problems that are important to them in their environments; that is, to study the cognitive processes by which people shape themselves and their environments to meet their needs. But he disagrees with Gardner in this important respect: Sternberg believes that regardless of the type of problem people are confronted with, they use a common set of cognitive processes to solve them. According to Sternberg, this is true whether the problems involve mathematical, spatial, linguistic, or interpersonal issues. Sternberg (1989) identifies three components involved in any type of problem solving, components that represent basic information processes that act on information we take in through the senses. He calls these *metacomponents*, *performance components*, and *knowledge-acquisition components* (see Figure 5.6).

Metacomponents of Intelligence. When attempting to solve real-world problems, intelligent people must make decisions about which strategies to use to solve them; how much time to allocate to arrive at a solution; the resources necessary; the best way to monitor a solution; and how to set up a system for obtaining feedback, attending to the feedback, and making sense of it. Sternberg refers to these as *executive skills*. As you can see, they relate to the regulation and control of problem solving. Thus they are similar to the metacognitive skills we studied in the information processing model above. Conventional intelligence tests do not test these metacomponents. Nevertheless, Sternberg stipulates that these executive skills are essential features of intelligent behavior, and, more importantly, that they can be taught.

Performance Components. Metacomponents regulate planning, monitoring, and decision making. Performance components actually carry out the processes involved in problem solving. They involve the use of cognitive strategies and include such matters as attending to stimuli, storing them in long-term memory, analyzing the features of problems, and retrieving information from working memory. These performance components work best to solve problems when they have become automated—when they are performed effortlessly and rapidly without conscious thought (for example, decoding meaning while reading). Again, conventional intelligence tests do not assess these components very well. But as we have seen in our discussion of cognitive strategies, they can be taught.

Knowledge-Acquisition Components. To solve real-world problems, learners must perform cognitive strategies with automaticity and regulate their use, and they must also acquire knowledge about the problem itself. Some of the skills involved in acquiring knowledge include distinguishing relevant from irrelevant information while reading, forming internal connections with incoming information so that concepts and principles can be formed, and building external connections with prior learning (what we have called *activation*). Sternberg believes that conventional intelligence tests can serve as good measures of the knowledge-acquisition components of intelligence. But he also believes that the skills involved in knowledge acquisition are learned and can be taught.

For Sternberg, intelligence and good information processing are one and the same. His message to teachers is clear—you can make your learners more intelligent in the following ways.

- 1. Give them real-world problems that are important in their culture and environment to solve.
- 2. Teach them general cognitive strategies that they can use to solve any problem.
- 3. Teach them metacognitive skills to help them regulate their use of cognitive strategies.
- 4. Show them how to acquire knowledge and provide practice opportunities, so that these skills become automatic.

Some Final Thoughts on Cognitive Learning Theory

We began this chapter by examining the thinking of a good information processor, Tesfaye. We saw that he knew a lot, strategized, and knew when to use these strategies. The main point of this chapter is that making your learners good thinkers involves more than helping them acquire knowledge. It requires that you both understand what is involved in good thinking and teach metacognitive strategies to enhance the cognitive processes of reception, availability, and activation. In the next chapter we will examine some of the best ways to do this in the classroom.

## Summing Up

This chapter introduced you to cognitive approaches to learning. Its main points were these:

- Cognitive psychologists believe that good thinking involves the use of cognitive strategies for finding and organizing information and remembering when and where to use it.
- Cognitive scientists use a variety of metaphors to describe the content and processes of good thinking, such as the mind as a computer, filing system, or information management system.
- Cognitive psychologists focus their interest on complex human thinking, such as concept and strategy learning, decision making, problem solving, and how learners construct knowledge.
- Cognitive strategies are general methods of thinking that improve learning across a variety of subject areas.
- Rehearsal, elaboration, and organization are three strategies that can be taught to your learners to improve their memory of what you teach.
- Comprehension monitoring is a term applied to cognitive strategies that help learners get meaning from what they read and that teach them to set goals, focus their attention, self-reinforce, and cope with problems.

- Metacognition—or thinking about thinking—involves the use of cognitive strategies for monitoring our own cognitive processes, such as thinking, learning, and remembering.
- Metacognitive instruction includes teaching your learners to: (1) attend to the effectiveness of cognitive strategies, (2) attribute differences to the relative effectiveness of a particular strategy, and (3) use the more effective strategy in future decision making.
- Good thinkers have a large knowledge base that includes both declarative knowledge and procedural knowledge, as well as general knowledge.
- The key components of the information processing model are immediate, working, and long-term memory.
- The information storage capacity of your learners' working memory can be enhanced by the active processing of information, such as taking notes, discussion, practice, and comprehension monitoring.
- The parallel distributed processing model (PDP) suggests that the minds of your learners may not always work in orderly, sequential ways. This model suggests that learners may figure things out without being given an orderly set of rules, may not always think logically or rationally when solving problems, and may construct their own meanings.
- The two major traditions in the study of intelligence are the classical tradition, which attempts to understand the structure of intelligence, and the revisionist tradition, which seeks to understand its processes.
- Gardner believes that we can learn about intelligence only by studying the cognitive processes people use when they are solving important problems. He describes seven cognitive abilities that help us solve these problems: logical-mathematical, linguistic, musical, spatial, bodily-kinesthetic, interpersonal, and intrapersonal.

• Sternberg believes that, regardless of the type of problem, there is a common set of cognitive processes learners can use.

For Discussion and Practice

- \*1. Why have cognitive psychologists chosen various metaphors to describe how the mind works? Which is their metaphor of choice?
- \*2. Regardless of the metaphor chosen, what basic elements do all cognitive approaches to learning share?
- \*3. In what respects do cognitive approaches to the study of learning differ from behavioral approaches?
- \*4. What is a cognitive learning strategy? Give an example of a cognitive learning strategy that you have used and that you would want to share with your learners.
- \*5. If you wanted to help your learners remember what you've taught, what three cognitive activities might you ask them to perform?
- \*6. If you wanted to help your learners improve their comprehension of what they've read, what skills would you teach them?
- 7. Write a brief classroom dialogue suitable to your subject or grade to illustrate the five stages of the IDEAL problem-solving strategy.
- \*8. What metacognitive instruction should you provide your learners to help them use cognitive strategies in your classroom?
- \*9. Provide an example of domain-specific knowledge and an example of general knowledge in your subject or grade level. On what basis did you make the distinction between these two types of knowledge?

- \*10. Identify two ways cognitive psychologists have classified knowledge, concepts, and principles that are built up and organized from birth to adulthood. Provide an example of each classification.
- \*11. What are some of the ways you could help your learners' working memory function more efficiently?
- \*12. Draw a weblike diagram illustrating your own version of a propositional network pertaining to the concept of "effective teaching."
  Of what importance are propositional networks in helping learners remember important concepts and principles?
- Use an example suitable to your teaching field to describe how learning might occur in the form of "pattern recognition" using the neural network model illustrated by Marshall (1990).
- \*14. Compare and contrast the views of intelligence held by Gardner and Sternberg with the view of intelligence you grew up with. In what ways does Gardner's view of intelligence differ from Sternberg's?

## Suggested Readings

Gagné, E.D., Yekovich, C.W., & Yekovich, F.R. (1993). *The cognitive psychology of school learning* (2nd ed.). New York: HarperCollins. This highly readable text tells what cognitive psychology is, how cognitive psychologists perform their work, and what they have found that is relevant to teaching. It also provides readers with a coherent explanatory framework to solve teaching and learning problems in the classroom.

Pressley, M. (1995). Advanced Educational Psychology For Educators, Researchers, and Policymakers. New York: HarperCollins. Includes several excellent chapters on cognitive psychology and cognitive learning theory, with numerous examples of how to use this knowledge to improve your classroom teaching.

Solso, R. L. (1988). *Cognitive psychology* (2nd ed.). Needham, MA: Allyn &Bacon. A book for those who want to explore not only the theories underlying cognitive approaches to learning but also the research methods and findings.

Cognitive psychologists cannot see good thinking, but they can use metaphors to study and describe it.

## Figure 5.1

Basic elements of the cognitive approach to learning. *Source:* Adapted from *Educational Psychology: A Cognitive Approach* (p. 55), by R. E. Mayer, 1987, New York: HarperCollins. Copyright © 1987 by Little, Brown Publishers. Reprinted by permission of HarperCollins College Publishers.

How can I teach my learners to become good thinkers?

**Cognitive strategies.** General methods of thinking that improve learning across a variety of subject areas.

What cognitive learning strategies can help my learners remember what I teach?

**Rehearsal.** Repeating to yourself what you are reading or hearing.

**Elaboration.** Associating what you are learning with a particular image or relating old learning to new.

**Keyword method.** An elaboration strategy whereby the learner transforms one of two related pieces of information into a keyword familiar to him- or herself to help remember the other piece.

**Organization.** Memory strategies whereby the learner groups or arranges the information being studied according to some system.

Teaching learners strategies to improve memory can have big payoffs in motivation and self-esteem, as well as in the learning of basic skills.

**Comprehension monitoring.** Cognitive strategies that help learners derive meaning from what they read.

What cognitive learning strategies can help my learners improve their comprehension of what they read?

Comprehension monitoring is one of a number of cognitive strategies that can help learners derive meaning from what they read. Applying Your Knowledge:

## **Teaching Memory Strategies**

**Jingles or Trigger Sentences.** *Jingles,* or trigger sentences, can cue sequential letters, patterns, or special historical dates. For example, most music students learn some variation of the phrase "Every Good Boy Does Fine" to recall the musical notes EGBDF on the lines of a treble staff. "Spring forward, fall backward" helps one remember which way to adjust clocks at the beginning and end of daylight saving time. Many school children can recite "In fourteen hundred and ninety-two, Columbus sailed the ocean blue." Such devices also can be used for recalling the steps of a mental strategy.

**Narrative Chaining.** *Narrative chaining* is the process of weaving a list of key words you wish to remember into a brief story. For example, if you need to memorize the key stages of a butterfly's life cycle (egg, larva, pupa, adult), you could invent a narrative such as this:

This morning I cooked an egg for breakfast, but I heated it so long that it looked like molten lava from a volcano. A pupil from a nearby school stopped by, and when he saw my egg-turned-lava, he yelled, "I'm just a pupil! You're the adult! Couldn't you cook an egg better than that?"

In this case, lava and pupil sound enough like larva and pupa to trigger memory of the correct words in the life cycle sequence.

Number Rhyme or Peg Word. A *number rhyme* (or peg word) mnemonic system uses words that rhyme with a sequence of numbers as a basis for developing odd, imaginative mental pictures that assist in memorizing a set of other, less related words. Using the life cycle of the butterfly as an example again, you might employ the number rhyme system this way: *one-sun:* Imagine a big fried egg hanging in the sky overhead in place of a shining sun.

*two-stew:* Imagine a bubbling stew erupting from a gigantic volcano under the fried egg, drying to form molten lava.

*three-sea:* Imagine a tiny, screaming pupil afloat on a swirling, angry sea where the hot lava sizzles as it meets the seawater.

*four-door:* Imagine a golden door in the side of the volcano that is opened by a gentle, helpful adult who reaches out to pull the pupil from the sea near the lava that was heated by the egglike sun.

**Chunking.** *Chunking* refers to grouping bits of information into sets of five to seven discrete pieces. If the sets are chunked into logical categories, the information is then doubly processed in a mental framework for improved recall. A common example is memorizing a grocery list by splitting it into logical categories (dairy products, vegetables, beverages, etc.) of several items each.

*Source:* Reprinted with the permission of Macmillan College Publishing Company from *Effective Teaching Methods,* 3rd ed., by G. D. Borich, 1996, Copyright © 1996 by Merrill/Macmillan Publishing Company, Inc.

Applying Your Knowledge:

Using Reading Comprehension Strategies

Summarization. Teach your learners the following summarization rules:

- 1. Delete trivial information.
- 2. Delete redundant information.

- 3. Substitute superordinate (inclusive) terms for specific details (for example, summarize a number of descriptive details under the superordinate term "large" or "frightening").
- 4. Integrate a series of actions under a superordinate or allinclusive action term (for example, summarize waking up, brushing teeth, eating breakfast, and so on as "getting up in the morning").
- 5. Select a topic sentence; invent a topic sentence if there is none.

Bean and Steenwyck (1984) instructed sixth-graders in the use of these rules and significantly improved their reading comprehension with a variety of reading material.

**Mental Imagery.** Teach your learners to create pictures or images in their minds to depict what they have read. For example, when the learner reads a potentially confusing fact, such as "an ecosystem is a specific community of living creatures and their environment," teach him to picture in his mind a natural scene that includes a variety of animals and plants. Learners can do the same for history passages, poems, current events articles, and so forth.

Sadoski (1983, 1985) taught these strategies to third- and fourth-graders and found that their recall of story details and understanding of what they read was greatly enhanced.

**Story Grammar Training.** Different types of texts, such as *narratives* (texts that tell stories) and *expository* texts (texts that convey information), have typical structures that students learn to recognize. For example, the structure, or *story grammar*, of a fable might go something like this: One animal encounters another animal, something happens to one of the animals or one animal does something to the other animal, the animal who was helped or harmed overcomes the obstacle or injury, the two animals meet at some future time, and one animal learns an important lesson. Mystery stories, romances, and science passages also have predictable structures. Teach your learners to ask themselves questions about this structure. For example, as they read stories, teach your learners to ask themselves:

- 1. Who is the main character?
- 2. Where and when did the story take place?
- 3. What did the main characters do?
- 4. How did the story end?
- 5. How did the main character feel?

Short and Ryan (1984) and Idol and Croll (1987) taught story grammars to 9-

to 12-year-olds that significantly improved their reading comprehension of stories.

**Metacognition.** Thinking about thinking; the use of cognitive strategies for finding and organizing information and remembering when and where to use them.

Applying Your Knowledge:

## Using the IDEAL Method

**Teacher:** Today we're going to think a little more about the greenhouse problem. Remember what we talked about yesterday. The PTA is giving us money to build a greenhouse, but we have a problem about how we can get the flowers and vegetable plants to grow inside a house when they're supposed to grow outside.

Student 1: First the letter *I*. You identify the problem.

**Teacher:** And what do we do when we identify a problem?

**Student 2:** We read the problem and try to figure out what we're supposed to answer or solve.

**Teacher:** OK. I'll try to identify one of the problems with the greenhouse and then ask one of you to do the same. One of the problems I see is how the plants get food. Anybody else?

Student 3: I see a problem: what about when it gets cold?

Teacher: So, what's the problem?

**Student 3:** Well, it's how do you make sure they have the right temperature to live?

**Teacher:** Good! What was another thing we talked about when you think about problems?

Student 4: Letter *D*! You define any words you don't understand in the problem.
Teacher: Why is this important?

**Student 4:** Well, you want to make sure you really understand the problem. Sometimes we use words and think we know what they mean but we really don't. So *D* reminds us to make sure we really know what we mean when we define the problem. **Teacher:** Good. I'll give you an example, then you give me one. What is a greenhouse? Are we all agreed on this?

Student 5: And the right temperature. What's that mean?

**Teacher:** Great. Now, what's the third thing we do when we think about solving a problem?

Applying Your Knowledge:

Teaching Metacognitive Knowledge

- Teach specific cognitive strategies for learning important information in each subject area. This might involve teaching specific strategies for vocabulary learning, spelling, reading comprehension, and so forth. Such strategies can involve basic rehearsal techniques, organizational strategies, or comprehension monitoring strategies. (For a comprehensive list of learning strategies see Weinstein, C. E., & Mayer, R. E. (1986). The Teaching of Learning Strategies. In M. C. Wittrock (ed.), *Handbook of Research on Teaching* (3rd ed.), pp. 315–327. New York: Macmillan.)
- 2. Once your learners demonstrate that they know how to use a given strategy, teach them to recognize when to use it and to monitor how it is helping them. One way to do this is to give them two equivalent tasks to learn (for example, two lists of vocabulary words; two reading passages) and have them learn one task using the strategy and the equivalent task not using the strategy.
- 3. Explicitly prompt the learners to attend to or monitor how the strategy is helping them and how not using the strategy affects them.
- 4. Have the learners record and compare how much they learned with each method.

- 5. Discuss with the learners how use of the strategy helped improve learning.
- 6. Have the learners express an intent to use the strategy the next time they are presented with a similar learning task.
- 7. Give the learners additional opportunities to use the strategy and monitor its effectiveness.

Which is more important to how much my learners are able to learn: prior knowledge or intelligence?

**Domain-specific knowledge.** Knowledge of facts, concepts, and principles pertaining to a specific area or topic.

**General knowledge.** Knowledge useful for learning across a variety of school tasks.

General knowledge enables middle-school learners to perform complex tasks and solve complex problems.

**Declarative knowledge.** Verbal information: the facts, concepts, principles, and theories we learn from lectures, studying textbooks, or watching television.

**Procedural knowledge.** Know-how knowledge: action sequences we use to complete tasks, such as booting a floppy disk or writing an outline.

**Automaticity.** Learning a procedure so thoroughly that it can be carried out quickly with little thinking or effort.

**Information processing model.** A model of learning that examines how we learn using the "mind as computer" metaphor.

**Parallel distributed processing model.** A model of learning that suggests that learners may not always learn in orderly, sequential ways, but instead use sources of information simultaneously to construct their own meanings.

## Figure 5.2

Basic elements of the human information processing system. *Source: The Cognitive Psychology of School Learning* (p. 40), by E. D. Gagné, C. W. Yekovich, and F. R. Yekovich, 1993, New York: HarperCollins. Copyright © 1993 by HarperCollins Publishers. Reprinted by permission of HarperCollins College Publishers.

**Immediate memory.** Our information storage capacity that holds sensory data for less than a second before it is lost or transferred to our working memory.

How can I use the information processing model of thinking to better understand how learning occurs?

What are some ways of getting and holding my learners' attention?

**Working memory.** The information storage capacity that receives data from immediate memory and holds it for about 10 to 20 seconds.

BORICP05.doc - 56

Applying Your Knowledge:

## Grabbing and Holding Your Learners' Attention

- Expectations are important in attention. At the start of a lesson, explanation, or demonstration, state a clear purpose and goal for the activity. For example: "Today we're going to learn how to write a capital letter *K*," or "I'm going to show you how to find the main idea in a paragraph."
- 2. Our visual, auditory, and tactile senses are primed to pick up on variations in stimuli—therefore, variety will grab learners' attention, but sameness will allow their attention to wander. As you teach, vary your voice intensity, pitch, and tone, move around the room, and display colorful, visually interesting overheads, charts, or chalkboard displays.
- 3. Your learners' attention will be drawn to things that have emotional meaning for them. Embedding learners' names in lessons or explanations (called "name-dropping"), or including people, places, and objects that you know are important to your learners will attract and sustain their attention.
- 4. A common complaint of learners is "Every day we do the same old thing." Surprise them! Start the lesson differently, stand in a different place, change the room arrangement, dress differently. In other words, grab their attention by defying their expectations.

**Decay theory.** A theory that holds that information dissolves or dissipates from our working memory unless it is rehearsed.

**Displacement theory.** A theory that holds that, once new information enters working memory, existing information is pushed out and replaced by incoming data.

**Interference theory.** A theory that holds that subsequent learning competes with prior learning and interferes with what is contained in working memory.

**Long-term memory.** The information storage capacity in which new information is integrated through rehearsal, elaboration, and organization with information that is already known or residing within long-term memory.

**Dual-coding theory.** A theory that holds that complex networks of verbal representations and images reside within long-term memory to promote long-term retention.

**Propositional networks.** Extensive networks of interconnected ideas stored in long-term memory that provide representations and images that help us retain information for a long time.

**Schema theory.** Cognitive structures of integrated units that organize large amounts of information.

#### Figure 5.3

A propositional network. *Source:* D. F. Dansereau, 1988, in C. F. Weinstein, E. T. Goetz, and P. A. Alexander (eds.), *Learning and Study Strategies: Issues in Assessment, Instruction, and Evaluation,* Orlando: Academic Press. Reprinted by permission.

What teaching strategies can I use to enhance my learners' reception, availability, and activation of the information I present?

### Figure 5.4

Three conditions for meaningful learning. *Source:* Adapted from *Educational Psychology: A Cognitive Approach* (p. 13), by R. E. Mayer, 1987, New York: HarperCollins. Copyright © 1987 by Little, Brown. Reprinted by permission of HarperCollins College Publishers.

Applying Your Knowledge:

Using the Information Processing Model to Promote Learning **Reception.** Learners must *receive* the information you want them to learn. Thus attention is of primary importance. To ensure attention:

- 1. Make frequent use of cues, signals, challenging questions, and other stimuli to prompt or remind your learners that they are about to learn something interesting.
- 2. Ask questions or call on learners frequently during your lessons, but use an unpredictable sequence. You want your learners to anticipate that they can be called on at any time during a lesson.
- 3. Vary your tone of voice, where you stand while teaching, and the arrangement of the room.
- 4. Surprise your learners.

**Availability.** Learners will quickly forget new information as it enters working memory unless they possess existing knowledge that they can relate it to. To ensure availability:

- 1. Start your lessons with reviews of information that was learned earlier.
- 2. Give your learners cues to help them recall what they have learned about a particular topic.

- 3. Ask questions to help them be more aware of what they have heard, seen, or read about the to-be-learned material.
- 4. Give learners summaries or overviews of lessons (called *advanced organizers* or *anticipatory sets*), which provide prior knowledge of a lesson before it actually starts.

**Activation.** For meaningful learning to occur, the learner must actively organize the incoming information (in other words, he must see the relationships among the facts and concepts) and relate this to information that has already been learned. This is called *building internal connections with incoming information* and *building external connections with existing information*. To ensure activation:

- 1. Before a lesson, show learners how the various facts, concepts, and principles are related. Use the overhead projector to show them an outline of the lessons for the coming day or week.
- 2. Periodically insert questions and summaries during your lessons to help them make connections to both the newly learned and previously learned material.
- 3. Teach cognitive strategies that help the learners become aware of the connections among what they are learning and have already learned (for example, taking lecture notes, constructing outlines).
- 4. Remember that conscious thinking and problem solving occur in working memory, which has a limited capacity. Teach learners strategies to prolong information in working memory and thus give them time to make comprehension automatic.

## Table 5.1

## Five Types of Arithmetic Word Problems

Change

Jeff loaded his printer with 300 sheets of paper. When he was done printing, there were 35 sheets of paper left. How many sheets of paper did Jeff use?

Group

Yesterday, Joe's Pizza Parlor sold 12 cheese pizzas, 15 pepperoni pizzas, and 4 vegetarian pizzas. How many pizzas were sold in all?

Compare

Carol can write 10 pages a day, and Ellen can write 5 pages a day. Who writes more—Carol or Ellen?

Restate

Rick writes twice as fast as Carol. Carol writes 10 pages a day. How fast does Rick write?

Vary

Ellen jogs 1 mile in 8 minutes. How long will it take her to run 5 miles?

Source: Marshall, 1990. Illustrated by Gagné, Yekovich, & Yekovich,

1990.

#### Figure 5.5

A neural-network model of word problem classification. *Source:* Adapted from Marshall, 1990.

Do my learners have to learn in orderly, sequential ways or can they use different sources of information simultaneously to construct their own meanings?

Is my learners' intelligence fixed, or is it made up of many specific abilities that I can improve through instruction?

Table 5.2

Intelligence	Possible Occupation	Core Components
Logical-mathematical	Scientist	Sensitivity to and capacity to discern
	Mathematician	logical or numerical patterns; ability
		to handle long chains of reasoning
Linguistic	Poet	Sensitivity to the sounds, rhythms,
	Journalist	and meanings of words; sensitivity to
		the different functions of language
Musical	Composer	Abilities to produce and appreciate
	Violinist	rhythm, pitch, and timbre; apprecia-
		tion of the forms of musical
		expressiveness
Spatial	Navigator	Capacities to perceive the visual-
	Sculptor	spatial world accurately and to ma-
		nipulate the mental representations
		that result
Bodily-kinesthetic	Dancer	Abilities to control one's body move-
	Athlete	ments and to handle objects skillfully

# The Seven Intelligences

Interpersonal	Therapist	Capacities to discern and respond
	Salesperson	appropriately to the moods, tem-
		peraments, motivations, and desires
		of other people
Intrapersonal	Person with detailed	Access to one's own feelings and the
	accurate self-knowledge	ability to discriminate among them
		and draw upon them to guide be-
		havior; knowledge of one's own
		strengths, weaknesses, desires, and
		intelligences

Source: "Multiple Intelligences Go to School: Education Implication of the Theory of Multiple Intelligences," by H. Gardner and T. Hatch, 1989. Educational Researcher, 18, (8), pp. 4–10.

#### Table 5.3

## Areas of Cognitive Ability Examined in Project Spectrum

#### Numbers

*Dinosaur Game:* designed as a measure of a child's understanding of number concepts, counting skills, ability to adhere to rules, and use of strategy. *Bus Game:* assesses a child's ability to create a useful notation system, perform mental calculations, and organize number information for one or more variables. Science

*Assembly Activity:* designed to measure a child's mechanical ability. Successful completion of the activity depends on fine-motor skills and visual-spatial, observation, and problem-solving abilities.

*Treasure Hunt Game:* assesses a child's ability to make logical inferences. The child is asked to organize information to discover the rule governing the placement of various treasures.

*Water Activity:* used to assess a child's ability to generate hypotheses based on observations and to conduct simple experiments.

*Discovery Area:* includes year-round activities that elicit a child's observations, appreciation, and understanding of natural phenomena.

### Music

*Music Production Ability:* designed to assess a child's ability to maintain accurate pitch and rhythm while singing, and to recall a song's musical properties. *Music Perception Activity:* assesses a child's ability to discriminate pitch. The activity consists of song recognition, error recognition, and pitch discrimination.

## Language

*Storyboard Activity:* measures a range of language skills including complexity of vocabulary and sentence structure, use of connectors, use of descriptive language and dialogue, and ability to pursue a story line.

*Reporting Activity:* assesses a child's ability to describe an event with regard to the following criteria: ability to report content accurately, level of detail, sentence structure, and vocabulary.

## Visual Arts

*Art Portfolios:* reviewed twice a year and assessed on criteria that include use of lines and shapes, color, space, detail, and representation and design. Children also participate in three structured drawing activities. The drawings are assessed on criteria similar to those used in the portfolio assessment.

#### Movement

*Creative Movement:* the ongoing movement curriculum focuses on children's abilities in five areas of dance and creative movement: sensitivity to rhythm, expressiveness, body control, generation of movement ideas, and responsiveness to music.

*Athletic Movement:* an obstacle course focuses on the types of skills found in many different sports, such as coordination, timing, balance, and power.

Social

*Classroom Model:* assesses a child's ability to observe and analyze social events and experiences in the classroom.

*Peer Instruction Checklist:* a behavioral checklist is used to assess the behaviors in which children engage when interacting with peers. Different patterns of behavior yield distinctive social roles, such as facilitator and leader.

*Source: Multiple Intelligence: The Theory in Practice* (pp. 91–92), by Howard Gardner, 1993, New York: Basic Books.

#### Figure 5.6

Sternberg's information processing model of intelligence, defining intelligence as adaptation to the real world. *Source:* From Sternberg, 1988.

#### Focus on

#### Robert J. Sternberg, Yale University

I became interested in my main area, the study of human intelligence, as a young child. Because of test anxiety, I did poorly on intelligence tests. I could hardly answer any questions at all. As a result, when I was in sixth grade, I was sent back to take an IQ test with fifth graders. What an embarrassment! In seventh grade, I did a science project on mental testing. Part of it was to develop my own test. Another part was to give a test I found in the adult section of the library, the Stanford-Binet, to some of my classmates. This got me into really bad trouble. The head school psychologist found out, came to my junior high school, and yelled at me for 40 minutes, ending with his plan to burn the book if I ever brought it into school again. That event crystallized my interest in the field.

My early research on intelligence, which I started in graduate school at Stanford, emphasizes the process of intelligence rather than static psychometric factors. I developed methods of componential analysis to figure out exactly how people solved problems that required intelligence, so that one could specify the processes used, the strategies into which the processes were combined, how information was processed mentally, and how quickly and well components were executed. After using this approach for several years, I decided it was not in itself adequate, because it assumed that the kinds of problems used on conventional tests adequately measure intelligence. Eventually, my thinking shifted to the triarchic theory, according to which there are creative and practical as well as analytic aspects to intelligence. We tend to undervalue these former two aspects, especially in schools, despite their great importance for success in life. There are a number of barriers to conducting research in intelligence. One is that it is a relatively low-prestige area in psychology. A second is that it tends to be fraught with political controversies, so that the science can get lost in debates that have nothing to do with what is being studied. A third problem is that there are enormous vested interests in maintaining the status quo. Testing companies have not always been in a great hurry to change their ways of thinking, and neither have many users of standardized tests.

Having to overcome the damage to my view of myself that resulted from my own low test scores was helpful to me, because it made me understand the effects low scores can have on people's self-esteem, sense of self-efficacy, and ability to proceed through the system. In my case, my low test scores when I was very young led to lower expectations on the part of teachers, which led to lower achievement, which I overcame only when I had a teacher in the fourth grade who had higher expectations for me.

My research has many practical applications in the classroom:

- Teach in a way that reaches children whose profiles of intelligence suggest strengths not just in memory and analytic abilities, but also in creative and practical abilities. I have written in various places about techniques that can be used to reach children who are not traditionally school smart.
- 2. Testing should emphasize creative and practical as well as memory and analytic aspects of intelligence.

- 3. Creativity involves more than abilities. In our investment theory of creativity, we emphasize personality, motivational, and environmental factors as well as ability. Teachers need to create a classroom environment that fosters creativity. Examples of things to encourage include: (a) active definition and redefinition of problems, (b) asking yourself whether you are getting stuck in a given approach to a problem, (c) willingness to take sensible risks, (d) willingness to surmount obstacles, (e) willingness to grow, (f) finding something you really love to do, and, most important, (g) willingness to defy the crowd in one's ideas.
- 4. Teachers tend to prefer and more positively evaluate students whose styles match theirs. Teachers therefore need to resist their natural tendency to value students who think the way they do. Teachers also need to explicitly teach varied styles of learning and thinking. Often, teachers find that students whom they thought were not intelligent in fact are, but were not learning well because the teacher's style of teaching did not match the student's style of learning.
- 5. I have also emphasized the importance of questioning strategies. In particular, students should be encouraged not only to answer, but also to ask good questions. They should also explore question-answering at their own pace. Ultimately, the questions that you ask yourself are at least as important, and often more important, than your answers to the questions that others ask you.

Questions marked with an asterisk are answered in the appendix.