What Would You Do?

Teachers’ Casebook

You know that your students need good study skills to do well in both their current and future classes. But many of the students just don’t seem to know how to study. They can’t read a longer assignment, understand it, and remember what they read. They have trouble completing larger projects—many wait until the last minute. They can’t organize their work or decide what is most important. You are concerned because they will need all of these skills and strategies as they progress through their education. You have so much material to cover to meet district guidelines, but many of your students are just drowning in the amount of work.

Critical Thinking

- What study skills do students need for your subject or class?
- What could you do to teach these skills, while still covering the material that will be on the proficiency or achievement tests the students will have to take in the spring?

Collaboration

With 3 or 4 members of your class, identify the learning skills and study strategies that students will need in a grade you might teach. Then analyze the study skills necessary for your class using this text.

W

e focused on the development of knowledge—how people make sense of and remember information and ideas—in the previous chapter. In this chapter, we consider complex cognitive processes that lead to understanding. Understanding is more than memorizing. It is more than retelling in your own words. Understanding involves appropriately transforming and using knowledge, skills, and ideas. These understandings are considered “higher-level cognitive objectives” in a commonly used system of educational objectives (Anderson & Krathwohl, 2001; Bloom, Engelhart, Frost, Hill, & Krathwohl, 1956). We will focus on the implications of cognitive theories for the day-to-day practice of teaching.

Because the cognitive perspective is a philosophical orientation and not a unified theoretical model, teaching methods derived from it are varied. In this chapter, we will first examine four important areas in which cognitive theorists have made suggestions for learning and teaching: concept learning, problem solving, creativity, and learning strategies and tactics. Finally, we will explore the question of how to encourage the transfer of learning from one situation to another to make learning more useful.

By the time you have completed this chapter, you should be able to answer these questions:

- What are the characteristics of a good lesson for teaching a key concept in your subject area?
- What are the steps in solving complex problems?
- What are the roles of problem representation, algorithms, and heuristics in problem solving?
- How can teachers encourage creativity in their students?
- How could you apply new learning strategies and tactics to prepare for tests and assignments in your current courses?
- What are three ways a teacher might encourage positive transfer of learning?
Learning and Teaching about Concepts

**STOP | THINK | WRITE** What makes a cup a cup? List the characteristics of cupness. What is a fruit? Is a banana a fruit? Is a tomato a fruit? How about a squash? A watermelon? A sweet potato? An olive? How did you learn what makes a fruit a fruit?

Most of what we know about cups and fruits and the world involves concepts and relations among concepts (Ashcraft, 2006). But what exactly is a concept? A concept is a category used to group similar events, ideas, objects, or people. When we talk about a particular concept such as student, we refer to a category of people who are similar to one another — they all study a subject. The people may be old or young, in school or not; they may be studying baseball or Bach, but they all can be categorized as students. Concepts are abstractions. They do not exist in the real world. Only individual examples of concepts exist. Concepts help us organize vast amounts of information into manageable units. For instance, there are about 7.5 million distinguishable differences in colors. By categorizing these colors into some dozen or so groups, we manage to deal with this diversity quite well (Bruner, 1973).

**Views of Concept Learning**

In early research, psychologists assumed that concepts share a set of defining attributes, or distinctive features. For example, books all contain pages that are bound together in some way (but what about electronic "books"). The defining attributes theory of concepts suggests that we recognize specific examples by noting key required features.

Since about 1970, however, these views about the nature of concepts have been challenged (Ashcraft, 2006). Although some concepts, such as equilateral triangle, have clear-cut defining attributes, most concepts do not. Take the concept of party. What are the defining attributes? You might have difficulty listing these attributes, but you probably recognize a party when you see or hear one (unless, of course, we are talking about political parties, or the other party in a lawsuit, where the sound might not help you recognize the "party"). What about the concept of bird? Your first thought might be that birds are animals that fly. But is an ostrich a bird? What about a penguin? A bat?

**Prototypes and Exemplars.** Current views of concept learning suggest that we have in our minds a prototype of a party and a bird — an image that captures the essence of each concept. A prototype is the best representative of its category. For instance, the best representative of the "birds" category for many North Americans might be a robin (Rosch, 1973). Other members of the category may be very similar to the prototype (sparrow) or similar in some ways but different in others (chicken, ostrich). At the boundaries of a category, it may be difficult to determine if a particular instance really belongs. For example, is a telephone "furniture"? Is an elevator a "vehicle"? Is an olive a "fruit"? Whether something fits into a category is a matter of degree. Thus, categories have fuzzy boundaries. Some events, objects, or ideas are simply better examples of a concept than others (Ashcraft, 2006).

Another explanation of concept learning suggests that we identify members of a category by referring to exemplars. Exemplars are our actual memories of specific birds, parties, furniture, and so on that we use to compare with an item in question to see if that item belongs in the same category as our exemplar. For example, if you see a strange steel-and-stone bench in a public park, you may compare it to the sofa in your living room to decide if the uncomfortable-looking creation is still for sitting or if it has crossed a fuzzy boundary into "sculpture."

Prototypes probably are built from experiences with many exemplars. This happens naturally because episodic memories of particular events tend to blur together over time, creating an average or typical sofa prototype from all the sofa exemplars you have experienced (Schwartz & Reisberg, 1991).
Concepts and Schemas. In addition to prototypes and exemplars, there is a third element involved when we recognize a concept—our schematic knowledge related to the concept. How do we know that counterfeit money is not “real” money, even though it perfectly fits our “money” prototype and exemplars? We know because of its history. The “wrong” people printed the money. So our understanding of the concept of money is connected with concepts of crime, forgery, the federal treasury, and many others.

Jacob Feldman (2003) suggests a final aspect of concept learning—the simplicity principle. Feldman says that when humans are confronted with examples, they induce the simplest category or rule that would cover all the examples. Sometimes it is easy to come up with a simple rule (triangles) and sometimes it is more difficult (fruit), but humans seek a simple hypothesis for collecting all the examples under one concept. Feldman suggests that this simplicity principle is one of the oldest ideas in cognitive psychology: “organisms seek to understand their environment by reducing incoming information to a simpler, more coherent, and more useful form” (p. 231). Does this remind you of the Gestalt principles of perception in Chapter 7?

Strategies for Teaching Concepts

WHAT WOULD YOU SAY?

You are interviewing for a job in a school that serves many immigrant families. The principal asks, “How would you teach abstract concepts to a student who just arrived from Somalia and can’t even read in her native language, much less English?”

Both prototypes and defining attributes are important in learning. Children first learn many concepts in the real world from the best examples or prototypes, pointed out by adults (Tennyson, 1981). But when examples are ambiguous (is an olive a fruit?), we may consult the defining attributes to make a decision. Olives are foods with seeds in the edible parts, which matches the defining attributes for fruits, so they must be fruits, even though they are not typical or prototypic fruits (Schunk, 2004).

Like the learning of concepts, the teaching of concepts can combine both defining attributes and prototypes. One approach to teaching about concepts is called concept attainment—a way of helping students construct an understanding of specific concepts and practice thinking skills such as hypothesis testing (Joyce, Weil, & Calhoun, 2006; Klausmeier, 1992).

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Teaching Concepts (II, A2)
Teachers devote much effort to the development of concepts that are vital in learning subject matter and skills. Understand the major approaches to teaching concepts and be able to describe their strengths and limitations.
An Example Concept-Attainment Lesson. Here is how a 5th-grade teacher helped his students learn about a familiar concept and practice thinking skills at the same time (Eggen & Kauchak, 2001, pp. 148-151). The teacher began a lesson by saying that he had an idea in mind and wanted students to “figure out what it is.” He placed two signs on a table—“Examples” and “Nonexamples.” Then he placed an apple in front of the “Examples” sign and a rock in front of the “Nonexamples” sign. He asked his students, “What do you think the idea might be?” “Things we eat” was the first suggestion. The teacher wrote “HYPOTHESES” on the board and, after a brief discussion of the meaning of “hypotheses,” listed “things we eat” under this heading. Next he asked for other hypotheses—“living things” and “things that grow on plants” came next. After some discussion about plants and living things, the teacher brought out a tomato for the “Examples” side and a carrot for the “Nonexamples.” Animated reconsideration of all the hypotheses followed these additions and a new hypothesis—“red things”—was suggested. Through discussion of more examples (peach, squash, orange) and nonexamples (lettuce, artichoke, potato), the students narrowed their hypothesis to “things with seeds in the parts you eat.” The students had “constructed” the concept of “fruit”—foods with seeds in the edible parts (or, a more advanced definition, any engorged ovary, such as a pea pod, nut, tomato, pineapple, or the edible part of the plant developed from a flower).

Lesson Components. Whatever strategy you use for teaching concepts, you will need four components in any lesson: examples and nonexamples, relevant and irrelevant attributes, the name of the concept, and a definition (Joyce, Weil, & Calhoun, 2006). In addition, visual aids such as pictures, diagrams, or maps can improve learning of many concepts (Anderson & Smith, 1987; Mayer, 2001).

Examples. More examples are needed in teaching complicated concepts and in working with younger or less knowledgeable students. Both examples and nonexamples (sometimes called positive and negative instances) are necessary to make the boundaries of the category clear. A discussion of why a bat is not a bird (nonexample) will help students define the boundaries of the bird concept.

Relevant and Irrelevant Attributes. The ability to fly, as we’ve seen, is not a relevant attribute for classifying animals as birds. Even though many birds fly, some birds do not (e.g., ostrich, penguin), and some nonbirds do (e.g., bats, flying squirrels). The ability to fly would have to be included in a discussion of the bird concept, but students should understand that flying alone does not define an animal as a bird.

Name. Simply learning a label does not mean the person understands the concept, although the label is necessary for the understanding. In the example above, students probably already used the “fruit” name, but may not have understood that tomatoes, squash, and avocados are fruits.

Definition. A good definition has two elements: a reference to any more general category for the new concept, and a statement of the new concept’s defining attributes (Klauer, 1976). For example, a fruit is food (general category) with seeds in the edible parts (defining attributes). An equilateral triangle is a plane, a simple, closed figure (general category), with three equal sides and three equal angles (defining attributes). This kind of definition helps place the concept in a schema of related knowledge.

In teaching some concepts, “a picture is worth a thousand words”—or at least a few hundred, as we saw in Chapter 7. Handling specific examples, or pictures of examples, helps young children learn concepts. For students of all ages, the complex concepts in history, science, and mathematics can often be illustrated in diagrams or graphs. For example, Anderson and Smith (1983) found that when their students just read about the
concept of light, only 20% could understand the role of reflected light in our ability to see objects. But when the students worked with diagrams such as the one in Figure 8.1, almost 90% understood the concept.

**Lesson Structure.** The fruit lesson above is an example of good concept teaching for several reasons. First, it is more effective to examine examples and nonexamples before discussing attributes or definitions (Joyce, Weil, & Calhoun, 2000). Start your concept lesson with prototypes, or best examples, to help the students establish the category. In the fruit lesson, the teacher began with the classic fruit example, an apple, then moved to less typical examples such as tomatoes and squash. These examples show the wide range of possibilities the category includes and the variety of irrelevant attributes within a category. Including fruits that have one seed or many, have a sweet taste or not, are different colors, and have thick or thin skin, will prevent **undergeneralization**, or the exclusion of some foods, such as squash, from their rightful place in the category fruit.

Nonexamples should be very close to the concept, but miss by one or just a few critical attributes. For instance, sweet potatoes and rhubarb are not fruits, even though sweet potatoes are sweet and rhubarb is used to make pies. Including nonexamples will prevent **overgeneralization**, or the inclusion of substances that are not fruits.

After the students seem to have grasped the concept under consideration, it is useful to ask them to think about the ways that they formed and tested their hypotheses. Thinking back helps students develop their metacognitive skills and shows them that different people approach problems in different ways (Joyce, Weil, & Calhoun, 2006).

**Extending and Connecting Concepts.** Once students have a good sense of a concept, they should use it. This might mean doing exercises, solving problems, writing, reading, explaining, or any other activity that requires them to apply their new understanding. This will connect the concept into the students' web of related schematic knowledge. One approach that you may see in some texts and workbooks for students above the primary

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*Undergeneralization* Exclusion of some true members from a category; limiting a concept.

*Overgeneralization* Inclusion of nonmembers in a category; overextending a concept.
TABLE 8.1
Phases of the Concept Attainment Model

There are three main phases in concept attainment teaching. First, the teacher presents
examples/counterexamples, and students identify the concept. Then the teacher checks for
understanding, and finally students analyze their thinking strategies.

<table>
<thead>
<tr>
<th>Phase One: Presentation of Data and Identification of Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher presents labeled examples.</td>
</tr>
<tr>
<td>Students compare attributes in positive and negative examples.</td>
</tr>
<tr>
<td>Students generate and test hypotheses.</td>
</tr>
<tr>
<td>Students state a definition according to the essential attributes.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phase Two: Testing Attainment of the Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students identify additional unlabeled examples as yes or no.</td>
</tr>
<tr>
<td>Teacher confirms hypotheses, names concept, and restates definitions according to essential attributes.</td>
</tr>
<tr>
<td>Students generate examples.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phase Three: Analysis of Thinking Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students describe thoughts.</td>
</tr>
<tr>
<td>Students discuss role of hypotheses and attributes.</td>
</tr>
<tr>
<td>Students discuss type and number of hypotheses.</td>
</tr>
</tbody>
</table>

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Concept Mapping (II, A2)
For advice and additional information about the creation and use of concept maps, go to the website Graphic Organizers (http://www.graphic.org/concept.html).

Connect and Extend to PRAXIS II™
Reasoning (II, A1)
Be able to distinguish between inductive and deductive reasoning. Explain the role that each plays in the learning of concepts.

Concept mapping. Student’s diagram of his or her understanding of a concept.
Discovery learning. Bruner’s approach, in which students work on their own to discover basic principles.
Inductive reasoning. Formulating general principles based on knowledge of examples and details.
Intuitive thinking. Making imaginative leaps to correct perceptions or workable solutions.

grades is concept mapping (Novak & Musonda, 1991). Students “diagram” their understanding of the concept, as Amy has in Figure 8.2. Amy’s map shows a reasonable understanding of the concept of “molecule,” but also indicates that Amy holds one misconception. She thinks that there is no space between the molecules in solids.

Table 8.1 summarizes the phases of the concept attainment model.

Teaching Concepts through Discovery

Jerome Bruner’s early research on thinking (Bruner, Goodnow, & Austin, 1956) inspired his interest in educational approaches that encourage concept learning and the development of thinking. Bruner’s work emphasized the importance of understanding the structure of a subject being studied, the need for active learning as the basis for true understanding, and the value of inductive reasoning in learning.

Structure and Discovery. Subject structure refers to the fundamental ideas, relationships, or patterns of the field—the essential information. Because structure does not include specific facts or details, the essential structure of an idea can be represented simply as a diagram, a set of principles, or a formula. According to Bruner, learning will be more meaningful, useful, and memorable for students if they focus on understanding the structure of the subject being studied.

In order to grasp the structure of information, Bruner believes, students must be active—they must identify key principles for themselves rather than simply accepting teachers’ explanations. This process has been called discovery learning. In discovery learning, the teacher presents examples and the students work with the examples until they discover the interrelationships—the subject’s structure. Thus, Bruner believes that classroom learning should take place through inductive reasoning, that is, by using specific examples to formulate a general principle. The concept attainment lesson on fruit above used this approach.

Discovery in Action. An inductive approach requires intuitive thinking on the part of students. Bruner suggests that teachers can nurture this intuitive thinking by encouraging students to make guesses based on incomplete evidence and then to confirm or disprove the guesses systematically (Bruner, 1960). After learning about ocean currents and the shipping industry, for example, students might be shown old maps of three harbors and asked to guess which one became a major port. Then, they could check their guesses through systematic research. Unfortunately, educational practices often discourage intuitive thinking by punishing wrong guesses and rewarding safe, but uncreative answers.
A distinction is usually made between pure discovery learning, in which the students work on their own to a very great extent, and guided discovery, in which the teacher provides some direction. Reviewing 30 years of research on pure discovery learning, Richard Mayer (2004) concludes:

Like some zombie that keeps returning from its grave, pure discovery continues to have its advocates. However, anyone who takes an evidence-based approach to educational practice must ask the same question: Where is the evidence that it works? In spite of calls for free discovery in every decade, the supporting evidence is hard to find. (p. 17)

Unguided or pure discovery may be appropriate for preschool children, but in a typical elementary or secondary classroom, unguided activities usually prove unmanageable and unproductive. For these situations, guided discovery is preferable. Students are presented with intriguing questions, baffling situations, or interesting problems: Why does the flame go out when we cover it with a jar? Why does this pencil seem to bend when you put it in water? What is the rule for grouping these words together? Instead of explaining how to solve the problem, the teacher provides the appropriate materials and encourages students to make observations, form hypotheses, and test solutions. Turn the page for more Guidelines to help you apply Bruner’s suggestions.
Guidelines: Applying Bruner’s Ideas

Present both examples and nonexamples of the concepts you are teaching.

**Examples:**
1. In teaching about mammals, include people, kangaroos, whales, cats, dolphins, and caneels as examples, and chickens, fish, alligators, frogs, and penguins as nonexamples.
2. Ask students for additional examples and nonexamples.

Encourage students to make intuitive guesses.

**Examples:**
1. Instead of giving a word’s definition, say, “Let’s guess what it might mean by looking at the words around it.”
2. Give students a map of ancient Greece and ask where they think the major cities were.
3. Don’t comment after the first few guesses. Wait for several ideas before giving the answer.
4. Use guiding questions to focus students when their discovery has led them too far astray.

Help students see connections among concepts.

**Examples:**
1. Ask questions such as these: What else could you call this apple? (Fruit) What do we do with fruit? (Eat) What do we call things we eat? (Food)
2. Use diagrams, outlines, and summaries to point out connections.

Pose a question and let students try to find the answer.

**Examples:**
1. How could the human hand be improved?
2. What is the relation between the area of one tile and the area of the whole floor?

For more information on Bruner and discovery learning, see: http://evolution.massey.ac.nz/assign2/11B/bruner.html

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Teaching Concepts through Exposition

In contrast to Bruner, David Ausubel (1963, 1977, 1982) believed that people acquire knowledge primarily through reception, not discovery. Concepts, principles, and ideas are presented and understood using deductive reasoning—from general ideas to specific cases, not discovered from specific cases leading to general concepts. Ausubel’s expository teaching model stresses what is known as meaningful verbal learning—verbal information, ideas, and relationships among ideas, taken together. Rote memorization is not meaningful learning, because material learned by rote is not connected with existing knowledge.

**Advance Organizers.** Ausubel’s strategy always begins with an advance organizer. This is an introductory statement broad enough to encompass all the information that will follow. The organizers can serve three purposes: They direct your attention to what is important in the ensuing material, they highlight relationships among ideas that will be presented, and they remind you of relevant information you already have.

In general, advance organizers fall into one of two categories, comparative and expository (Mayer, 1984). Comparative organizers activate (bring into working memory) already existing schemas. They remind you of what you already know, but may not realize is relevant. A comparative advance organizer for a history lesson on revolutions might be a statement that contrasts military uprisings with the physical and social changes involved in the Industrial Revolution; you could also compare the common aspects of the French, English, Mexican, Russian, Iranian, and American revolutions (Salomon & Perkins, 1989).

In contrast, expository organizers provide new knowledge that students will need to understand the upcoming information. In an English class, you might begin a large thematic unit on rites of passage in literature with a very broad statement of the theme and why it has been so central in literature—something like, “A central character coming of age must learn to know himself or herself, often makes some kind of journey of self-discovery, and must decide what in the society is to be accepted and what rejected.”

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Chapter 8: Complex Cognitive Processes
The general conclusion of research on advance organizers (Corkill, 1992; Langran-Fox, Waycott, & Albert, 2000; Morin & Miller, 1998) is that they do help students learn, especially when the material to be learned is quite unfamiliar, complex, or difficult—if two conditions are met. First, to be effective, the organizer must be understood by the students. This was demonstrated dramatically in a study by Dinnel and Glover (1985). They found that instructing students to paraphrase an advance organizer—which, of course, requires them to understand its meaning—increased the effectiveness of the organizer. Second, the organizer must really be an organizer: It must indicate relations among the basic concepts and terms that will be used. Concrete models, diagrams, or analogies seem to be especially good organizers (Robinson, 1998; Robinson & Kiewra, 1995).

**Steps in an Expository Lesson.** After the advance organizer, the next step is to present content in terms of similarities and differences using specific examples, perhaps provided by the students themselves. Assume you are teaching the coming-of-age theme in literature, using *The Diary of Anne Frank* and *The Adventures of Huckleberry Finn*. As the students read, you might ask them to compare the central character's growth, state of mind, and position in society with characters from other novels, plays, and films (connect to students' prior knowledge). Then students can compare Anne Frank's inner journey with Huck Finn's trip down the Mississippi. As comparisons are made, you should underscore the goal of the lesson and elaborate the advance organizer.

The best way to point out similarities and differences is with examples. Huck Finn's and Anne Frank's dilemmas must be clear. Finally, when all the material has been presented, ask students to discuss how the examples can be used to expand on the original advance organizer. The phases of expository teaching are summarized in Figure 8.3.

Expository teaching is more developmentally appropriate for students at or above later elementary school, that is, around the 5th or 6th grade (Luiten, Ames, & Ackerson, 1980). The Guidelines on the next page should help you follow the main steps in expository teaching.
Guidelines: Applying Ausubel’s Ideas

Use advance organizers.

**Examples:**

1. **English:** Shakespeare used the social ideas of his time as a framework for his plays—Julius Caesar, Hamlet, and Macbeth dealt with concepts of natural order, a nation as the human body, etc.

2. **Social studies:** Geography dictates economy in preindustrialized regions or nations.

3. **History:** Important concepts during the Renaissance were symmetry, admiration of the classical world, the centrality of the human mind.

Use a number of examples.

**Examples:**

1. In a mathematics class, ask students to point out all the examples of right angles that they can find in the room.

2. In teaching about islands and peninsulas, use maps, slides, models, postcards.

Focus on both similarities and differences.

**Examples:**

1. In a history class, ask students to list the ways in which the North and South were alike and different before the Civil War.

2. In a biology class, ask students how they would transform spiders into insects or an amphibian into a reptile.

For more information on advance organizers, see: [http://moodle.edumce.edu/wikied/index.php/Advance_organizers](http://moodle.edumce.edu/wikied/index.php/Advance_organizers)

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Reaching Every Student: Learning Disabilities and Concept Teaching

A recent approach to teaching concepts that also emphasizes connections with prior knowledge is called **analogue instruction** (Bulgrin, Deisher, Schumaker, & Lenz, 2000). This approach has proved helpful for teaching scientific or cultural knowledge in heterogeneous secondary classes that include students who are less academically prepared and students with learning disabilities. In secondary classrooms, as the amount and complexity of content increases, these students are especially at risk for failure. The goal of analogue instruction is to identify knowledge that these students already have in memory that can be used as a starting point for learning the new, complex material. Analogies have long been used in problem solving, as you will see in the next section, but until recently, studies of analogies in teaching content have been rare.

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Problem Solving

**What would you say?**

You’re interviewing with the district superintendent for a position as a school psychologist. The man is known for his unorthodox interview questions. He hands you a pad of paper and a ruler and says, “Tell me, what is the exact thickness of a single sheet of paper?”

This is a true story—I was asked the paper thickness question in an interview years ago. The answer was to measure the thickness of the entire pad and divide by the number of pages in the pad. I got the answer and the job, but what a tense moment that was. I suppose the superintendent was interested in my ability to solve problems—under pressure!

A **problem** has an initial state (the current situation), a goal (the desired outcome), and a path for reaching the goal (including operations or activities that move you toward the goal). Problem solvers often have to set and reach subgoals as they move toward the final solution. For example, if your goal is to drive to the beach, but at the first
stop sign you skid through the intersection, you may have to reach a subgoal of fixing your brakes before you can continue toward the original goal (Schunk, 2004). Also, problems can range from well-structured to ill-structured, depending on how clear-cut the goal is and how much structure is provided for solving the problem. Most arithmetic problems are well-structured, but finding the right college major is ill-structured—many different solutions and paths to solutions are possible. Life presents many ill-structured problems.

**Problem solving** is usually defined as formulating new answers, going beyond the simple application of previously learned rules to achieve a goal. Problem solving is what happens when no solution is obvious—when, for example, you can’t afford new brakes for the car that skidded on the way to the beach (Mayer & Wittrock, 1996). Some psychologists suggest that most human learning involves problem solving (Anderson, 1993).

There is a debate about problem solving. Some psychologists believe that effective problem-solving strategies are specific to the problem area. That is, the problem-solving strategies in mathematics are unique to math; the strategies in art are unique to art, and so on. The other side of the debate claims that there are some general problem-solving strategies that can be useful in many areas. Actually, there is evidence for both sides of the argument. In their research with 8- to 12-year-olds, Robert Kail and Lynda Hall (1999) found that both domain-specific and general factors affected performance on arithmetic word problems. The influences were arithmetic knowledge—assessed by the time needed and errors produced in solving simple addition and subtraction problems—and general information-processing skills, including reading and information processing time and, to a lesser extent, memory span.

It appears that people move between general and specific approaches, depending on the situation and their level of expertise. Early on, when we know little about a problem area or domain, we can rely on general learning and problem-solving strategies to make sense of the situation. As we gain more domain-specific knowledge (particularly procedural knowledge about how to do things in the domain), we consciously apply the general strategies less and less; our problem solving becomes more automatic. But if we encounter a problem outside our current knowledge, we may return to relying on general strategies to attack the problem (Alexander, 1992, 1996; Shuell, 1990).

Let’s consider general problem-solving strategies first. Think of a general problem-solving strategy as a beginning point, a broad outline. Such strategies usually have five stages (Derry, 1991; Gallini, 1991; Gick, 1986). John Bransford and Barry Stein (1993) use the acronym IDEAL to identify the five steps:

1. **I**dentify problems and opportunities.
2. **D**efine goals and represent the problem.
3. **E**xplore possible strategies.
4. **A**nticipate outcomes and Act.
5. **L**ook back and Learn.

We will examine each of these steps because they are found in many approaches to problem solving.

**Identifying: Problem Finding**

The first step, identifying that a problem exists and treating the problem as an opportunity, begins the process. This is not always straightforward. There is a story about tenants who were angry because the elevators in their building were slow. Consultants hired to “fix the problem” reported that the elevators were no worse than average and that improvements would be very expensive. One day, as the building supervisor watched people waiting impatiently for an elevator, he realized that the problem was not slow elevators, but the fact that people were bored; they had nothing to do while they waited. When the boredom problem was identified and seen as an opportunity to improve the “waiting experience,” the simple solution of installing a mirror by the elevator on each floor eliminated complaints.

**Connect and Extend to the Research**

You might want to note that, although interest in problem solving is great today, many of the early ideas of John Dewey are consistent with the recent emphasis on teaching students to be effective problem solvers.
Identifying the problem is a critical first step. Research indicates that people often
hurry through this important step and "leap" to naming the first problem that comes to
mind ("the elevators are too slow"). Experts in a field are more likely to spend time care-
fully considering the nature of the problem (Bruning, Schraw, Norby, & Runyon, 2004).
Finding a solvable problem and turning it into an opportunity is the process behind
many successful inventions, such as the ballpoint pen, garbage disposal, appliance timer,
alarm clock, self-cleaning oven, and thousands of others.

Once a solvable problem is identified, what next?

Defining Goals and Representing the Problem

Let's take a real problem: The machines designed to pick tomatoes are damaging the
tomatoes. What should we do? If we represent the problem as a faulty machine design,
then the goal is to improve the machine. But if we represent the problem as a faulty des-
ign of the tomatoes, then the goal is to develop a tougher tomato. The problem-solving
process follows two entirely different paths, depending on which representation and goal
are chosen (Bransford & Stein, 1993). To represent the problem and set a goal, you have
to focus attention on relevant information, understand the words of the problem, and ac-
trive the right schema to understand the whole problem.

STOP | THINK | WRITE  If you have black socks and white socks in your drawer,
mixed in the ratio of four to five, how many socks will you have to take out to make sure
you have a pair the same color (adapted from Sternberg & Davidson, 1982)? •

Focusing Attention. Representing the problem often requires finding the relevant in-
formation and ignoring the irrelevant details. For example, what information was relevant
in solving the above sock problem? Did you realize that the information about the four-
to-five ratio of black socks to white socks is irrelevant? As long as you have only two dif-
ferent colors of socks in the drawer, you will have to remove only three socks before two of
them have to match.

Understanding the Words. The second task in representing a story problem is under-
standing the meaning of the words and sentences (Mayer, 1992). For example, the main
stumbling block in representing many word problems is the students' understanding of
part-whole relations (Cummins, 1991). Students have trouble figuring out what is part of
what, as is evident in this dialogue between a teacher and a 1st grader:

Teacher: Pete has three apples. Ann also has some apples. Pete and Ann have nine
apples altogether. How many apples does Ann have?
Student: Nine.
Teacher: Why?
Student: Because you just said so.
Teacher: Can you retell the story?
Student: Pete had three apples. Ann also had some apples. Ann had nine apples. Pete
also has nine apples. (Adapted from De Corte & Verschaffel, 1985, p. 19)

The student interprets "altogether" (the whole) as "each" (the parts). Sometimes, students
are taught to search for key words (more, less, greater, etc.); pick a strategy or formula based
on the key words (more means "add"), and apply the formula. Actually, this gets in the way
of forming a conceptual understanding of the whole problem.

Understanding the Whole Problem. The third task in representing a problem is to as-
semble all the relevant information and sentences into an accurate understanding or
translation of the total problem. This means that students need to form a conceptual
model of the problem—they have to understand what the problem is really asking
(Jonassen, 2003). Consider this example.

STOP | THINK | WRITE  Two train stations are 50 miles apart. At 2 a.m. one Saturday
afternoon, two trains start toward each other, one from each station. Just as the trains pull

Connect and Extend
to Other Chapters

Piaget (Chapter 2) identified chil-
dren's difficulties with part-whole
relations years ago when he asked
questions such as, "There are
six daisies and two daffodils; are
there more daisies or flowers?"
Young children usually answer,
"Daisies!"
out of the stations, a bird springs into the air in front of the first train and flies ahead to the front of the second train. When the bird reaches the second train it turns back and flies toward the first train. The bird continues to do this until the trains meet. If both trains travel at the rate of 25 miles per hour and the bird flies at 100 miles per hour, how many miles will the bird have flown before the trains meet? (Posner, 1973)

Your interpretation of the problem is called a translation because you translate the problem into a schema that you understand. If you translate this as a distance problem and set a goal ("I have to figure out how far the bird travels before it meets the oncoming train and turns around, then how far it travels before it has to turn again, and finally add up all the trips back and forth"), then you have a very difficult task on your hands. But there is a better way to structure the problem. You can represent it as a question of time and focus on the time the bird is in the air. The solution could be stated like this:

The trains are going the same speed so they will meet in the middle, 25 miles from each station. This will take one hour because they are traveling 25 mph. In an hour, the bird will cover 100 miles because it is flying at 100 miles per hour. Easy!

Research shows that students can be too quick to decide what a problem is asking. Once a problem is categorized—“Aha, it’s a distance problem!”—a particular schema is activated. The schema directs attention to relevant information and sets up expectations for what the right answer should look like (Kalyuga, Chandler, Tuovinen, & Sweller, 2001; Reimann & Cli, 1989).

When students lack the necessary schemas to represent problems, they often rely on surface features of the situation and represent the problem incorrectly, like the student who wrote “15 + 24 = 39” as the answer to, “Joan has 15 bonus points and Louise has 24. How many more does Louise have?” This student saw two numbers and the word “more,” so he applied the add to get more procedure. When students use the wrong schema, they overlook critical information, use irrelevant information, and may even misread or misremember critical information so that it fits the schema. But when students use the proper schema to represent a problem, they are less likely to be confused by irrelevant information or tricky wording, such as more in a problem that really requires subtraction (Resnick, 1981). Figure 8.4 gives examples of different ways students might represent a simple mathematics problem.
Translation and Schema Training. How can students improve translation and schema selection? To answer this question, we often have to move from general to area-specific problem-solving strategies because schemas are specific to content areas. In mathematics, for example, it appears that students benefit from seeing many different kinds of example problems worked out correctly for them. The common practice of showing students a few examples, then having students work many problems on their own, is less effective. Worked-out examples are helpful especially when problems are unfamiliar or difficult and when students have less knowledge (Cooper & Sweller, 1987). When students are learning, worked-out examples should deal with one source of information at a time (Marcus, Cooper, & Sweller, 1996). Ask students to compare examples. What is the same about each solution? What is different? Why?

The same procedures may be effective in areas other than mathematics. Adrieune Lee and Laura Hutchinson (1998) found that undergraduate students learned more when they had examples of chemistry problem solutions that were annotated to show an expert problem solver’s thinking at critical steps. In Australia, Slava Kalyuga and colleagues (2001) found that worked-out examples helped apprentices to learn about electrical circuits when the apprentices had less experience in the area. Asking students to reflect on the examples helped too; thus, both explanation and reflection can make worked-out examples more effective. Some of the benefit from worked-out examples comes when students use the examples to explain to themselves what is happening at each step or to check their understanding by anticipating the next step; in this way, students have to be mentally engaged in making sense of the examples (Atkinson, Renkl, & Merrill, 2003).

Familiar examples can serve as analogies or models for solving new problems. But beware. Novices are likely to remember the surface features of an example or case instead of the deeper meaning or the structure. It is the meaning or structure, not the surface similarities, that help in solving new, analogous problems (Gentner, Lowenstein, & Thompson, 2003). I have heard students complain that the test preparation problems in their math classes were about river currents, but the test asked about wind speed. They protested, “There were no problems about boats on the test!” In fact, the problems on the test about wind were solved in exactly the same way as the “boat” problems, but the students were focusing only on the surface features. One way to overcome this tendency is to have students compare examples or cases so they can develop a general problem-solving schema that captures the common structure, not the surface features, of the cases (Gentner et al., 2003).

How else might students develop the schemas they will need to represent problems in a particular subject area? Mayer (1983b) has recommended giving students practice in the following: (1) recognizing and categorizing a variety of problem types; (2) representing problems—either concretely in pictures, symbols, or graphs, or in words; and (3) selecting relevant and irrelevant information in problems.

The Results of Problem Representation. There are two main outcomes of the problem representation stage of problem solving, as shown in Figure 8.5. If your representation of the problem suggests an immediate solution, your task is done. In one sense, you haven’t really solved a new problem; you have simply recognized the new problem as a “disguised” version of an old problem that you already know how to solve. This has been called schema-driven problem solving. In terms of Figure 8.5, you have taken the schema-activated route and have proceeded directly to a solution. But what if you have no existing way of solving the problem or if your activated schema fails? Time to search for a solution!

Exploring Possible Solution Strategies

If you do not have existing schemas that suggest an immediate solution, then you must take the search-based route indicated in Figure 8.5. Obviously, this path is not as efficient as activating the right schema, but sometimes it is the only way. In conducting your search for a solution, you have available two general kinds of procedures: algorithmic and heuristic.

Algorithms. An algorithm is a step-by-step prescription for achieving a goal. It usually is domain-specific; that is, it is tied to a particular subject area. In solving a problem, if
you choose an appropriate algorithm and implement it properly, a right answer is guaranteed. Unfortunately, students often apply algorithms unsystematically. They try first this, then that. They may even happen on the right answer, but not understand how they found it. For some students, applying algorithms haphazardly could be an indication that formal operational thinking and the ability to work through a set of possibilities systematically, as described by Piaget, is not yet developed.

Many problems cannot be solved by algorithms. What then?

**Heuristics.** A heuristic is a general strategy that might lead to the right answer. Because many of life's problems (careers, relationships, etc.) are not straightforward and have ill-defined problem statements and no apparent algorithm, the discovery or development of effective heuristics is important (Korf, 1999). Let's examine a few.

In means-ends analysis, the problem is divided into a number of intermediate goals or subgoals, and then a means of solving each intermediate subgoal is figured out. For example, writing a 20-page term paper can seem an insurmountable problem for some students. They would be better off breaking this task into several intermediate goals, such as selecting a topic, locating sources of information, reading and organizing the information, making an outline, and so on. As they attack a particular intermediate goal, they may find that other goals arise. For example, locating information may require that they find someone to refresh their memory about using the library computer search system. Keep in mind that psychologists have yet to discover an effective heuristic for students who are just starting their term paper the night before it is due.

A second aspect of means-ends analysis is distance reduction, or pursuing a path that moves directly toward the final goal. People tend to look for the biggest difference between the current state of affairs and the goal and then search for a strategy that reduces the difference. We resist taking detours or making moves that are indirect as we search for the quickest way to reach the goal. So when you realize that reaching the goal of completing a term paper may require a detour of relearning the library computer search system, you may resist at first because you are not moving directly and quickly toward your final objective (Anderson, 1993).

Some problems lend themselves to a working-backward strategy, in which you begin at the goal and move back to the unsolved initial problem. Working backward is sometimes an effective heuristic for solving geometry proofs. It can also be a good way to set intermediate deadlines ("Let's see, if I have to submit this chapter in three weeks, Connect and Extend to Your Teaching/Portfolio

The following five heuristics that might help students solve college math problems are from Schoenfeld (1979):

1. Draw a diagram, if possible.
2. If the problem has an "N" that takes on integer values, try substituting numbers such as 1, then 2, then 3, then 4 for the "N," and look for a pattern in the results.
3. If you are trying to prove a statement, for example, "If X is true, then Y is true," try proving the contrapositive, "If X is false, then Y is false," or try assuming the statement you want to prove is false and look for a contradiction.
4. Try solving a similar problem with fewer variables.
5. Try to set up subgoals.

Heuristic  General strategy used in attempting to solve problems.

Means-ends analysis  Heuristic in which a goal is divided into subgoals.

Working-backward strategy  Heuristic in which one starts with the goal and moves backward to solve the problem.
One of the advantages of having students work in groups in problem-solving situations is that they will be called on to explain their proposed solutions to one another. Putting solutions into words usually improves problem solving.

Connect and Extend to Your Teaching/Portfolio

Guidelines for encouraging problem solving in children:
1. Provide problems, not just solutions.
2. Encourage viewing problems from different angles.
3. Make sure students have necessary background information.
4. Make sure students understand the problem.
   - Make accurate and useful representation.
   - Understand through associations and analogies.
5. Help students tackle the problem systematically.
   - Verbalize.
   - Describe and compare.
6. Practice with worked-out examples.

then it has to be in the mail by the 28th, so I should have a first draft finished by the 11th”.

Another useful heuristic is analogical thinking (Copi, 1961; Center et al., 2003), which limits your search for solutions to situations that have something in common with the one you currently face. When submarines were first designed, for example, engineers had to figure out how battleships could determine the presence and location of vessels hidden in the depths of the sea. Studying how bats solve an analogous problem of navigating in the dark led to the invention of sonar.

Analogical reasoning can lead to faulty problem solving, too. When word processors first came out, some people used the analogy of the typewriter and failed to take advantage of the computer's features. They were focusing on the surface similarities. It seems that people need knowledge in both the problem domain and the analogy domain in order to use an analogy effectively (Cagné, Yekovich, & Yekovich, 1993). In addition, they must focus on meaning, and not surface similarities when forming the analogies.

Putting your problem-solving plan into words and giving reasons for selecting it can lead to successful problem solving (Lee & Hitchinson, 1998). You may have discovered the effectiveness of this verbalization process accidentally, when a solution popped into your head as you were explaining a problem to someone else.

Anticipating, Acting, and Looking Back

WHAT WOULD YOU SAY?

You are interviewing with chair of the department. She asks, “What do you think about letting students use calculators and spell checkers? Do you think this is making learning too easy?”

After representing the problem and exploring possible solutions, the next step is to select a solution and anticipate the consequences. For example, if you decide to solve the damaged tomato problem by developing a tougher tomato, how will consumers react? If you take time to learn a new graphics program to enhance your term paper (and your grade), will you still have enough time to finish the paper?

After you choose a solution strategy and implement it, evaluate the results by checking for evidence that confirms or contradicts your solution. Many people tend to stop working before reaching the best solution and simply accept an answer that works
in some cases. In mathematical problems, evaluating the answer might mean applying a checking routine, such as adding to check the result of a subtraction problem or, in a long addition problem, adding the column from bottom to top instead of top to bottom. Another possibility is estimating the answer. For example, if the computation was $11 \times 21$, the answer should be around 200, because $10 \times 20$ is 200. A student who reaches an answer of 2,311 or 23 or 562 should quickly realize these answers cannot be correct. Estimating an answer is particularly important when students rely on calculators or computers, because they cannot go back and spot an error in the figures. See the Point/Counterpoint for opinions on the use of technology in checking answers.

Point/Counterpoint

Should Students Be Allowed to Use Calculators and Spell Checkers?

Not all educators believe that teachers should allow students to use calculators and other technical tools for performing operations and proofing work.

**Point** Calculators and spell checkers are crutches that harm learning.

When I polled my graduate class of experienced teachers and principals, I got various opinions, such as: “When students are given calculators to do math in the early grades, most of them never learn rudimentary mathematical concepts; they only learn to use the calculator” and “To learn math, students need repetition and practice on the concepts to remember the operations—calculators get in the way.” In a summary of the issue online, Nancy Ayres (http://www.math.twu.edu/history/topics/calculators.html#calc) noted, “David Gelernter, professor of computer science at Yale University, believes calculators should be totally eliminated from the classroom. He feels that allowing children to use calculators produces adults who can’t do basic arithmetic, doomed to wander through life in a numeric haze. In 1997, California legislation would prohibit the use of calculators in schools prior to the sixth grade. Whereas, the state of Virginia purchased 200,000 graphing calculators to be used by all middle school and high school math students.”

In terms of word processing, results of the National Assessment of Educational Progress (1997) indicated that even though the use of word processors by 11th graders increased from 19% in 1984 to 96% in 1997, the average writing scores of 11th graders declined during those years.

**Counterpoint** Calculators and spell checkers support learning.

Just because students learned mathematics in the past with paper-and-pencil procedures and practice does not mean that this is the best way to learn. Today, we have to consider each teaching situation on a case-by-case basis to determine if paper-and-pencil procedures or technology or some combination provides the best way to learn (Waits & Demana, 2000). For example, in the Third International Mathematics and Science Study (TIMSS, 1998), on every test at the advanced level, students who said that they used calculators in their daily math coursework performed much better than students who rarely or never used calculators. In fact, rather than eroding basic skills, the research on calculators over the past decade has found that using calculators has positive effects on students’ problem-solving skills and attitudes toward math (Waits & Demana, 2000).

What about word processors and spelling checkers? Priscilla Norton and Debra Sprague (2001) suggest that “no other technology resource has had as great an impact on education as word processing” (p. 78). They list the following effects: Word processing enhances learners’ perceptions of themselves as “real” writers, lets students reflect on the thinking that goes on behind the writing, facilitates collaborative writing, and helps students be more critical and creative in their writing.

In my class, an advisor working with undergraduate engineering students pointed out another plus for technology: “We have many international students who have an average-to-good command of English. In my opinion, they need Spellcheck to catch the errors as well as to ‘teach’ them the corrected form. Spellcheck is at times a nuisance to us by questioning everything, but I think it’s very helpful to ESL students and for general proofreading purposes.”

**What do you think?**

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1Thanks to Ohio State students Debbie Lanum and Charles Page for sharing their ideas.
Factors That Hinder Problem Solving

**STOP | THINK | WRITE** You enter a room. There are two ropes suspended from the ceiling. You are asked by the experimenter to tie the two ends of the ropes together and are assured that the task is possible. On a nearby table are a few tools, including a hammer and pliers. You grab the end of one of the ropes and walk toward the other rope. You immediately realize that you cannot possibly reach the end of the other rope. You try to extend your reach using the pliers but still cannot grasp the other rope. What can you do? (Maier, 1933)

**Fixation.** Problem solving requires seeing things in new ways. The rope problem can be solved if you tie the hammer or the pliers to the end of one rope and start swinging it like a pendulum. Then you will be able to catch it while you are standing across the room holding the other rope. You can use the weight of the tool to make the rope come to you instead of trying to stretch the rope. People often fail to solve this problem, because they focus on conventional uses for materials. This difficulty is called functional fixedness (Duncker, 1945). In your everyday life, you may often exhibit functional fixedness. Suppose a screw on a dresser-drawer handle is loose. Will you spend 10 minutes searching for a screwdriver or will you fix it with a ruler edge or a dime?

Another kind of fixation that blocks effective problem solving is response set, getting stuck on one way of representing a problem. Try this:

**STOP | THINK | WRITE** In each of the four matchstick arrangements below, move only one stick to change the equation so that it represents a true equality such as \( V = V \).

\[
\begin{align*}
V & = VII \\
VI & = XI \\
XII & = VII \\
VI & = I
\end{align*}
\]

You probably figured out how to solve the first example quite quickly. You simply move one matchstick from the right side over to the left to make \( VI = VI \). Examples two and three can also be solved without too much difficulty by moving one stick to change the \( V \) to an \( X \) or vice versa. But the fourth example (taken from Rauschkep & Ilanough, 1977) probably has you stumped. To solve this problem, you must change your response set or switch schemas, because what has worked for the first three problems will not work this time. The answer here lies in changing from Roman numerals to Arabic numbers and using the concept of square root. By overcoming response set, you can move one matchstick from the right to the left to form the symbol for square root; the solution reads \( \sqrt{1} \), which is simply the symbolic way of saying that the square root of 1 equals 1. Recently, a creative reader of this text e-mailed some other solutions. Jamaal Allan, a masters' student at Pacific University, pointed out that you could use any of the matchsticks to change the \( = \) sign to \( \neq \). Then, the last example would be \( V \neq I \) or 5 does not equal 2, an accurate statement. He suggested that you also might move one matchstick to change \( = \) to \( < \) or \( > \), and the statements would still be true (but not equalities as specified in the problem above). Can you come up with any other solutions?

**Some Problems with Heuristics.** We often apply heuristics automatically to make quick judgments; that saves us time in everyday problem solving. The mind can react automatically and instantaneously, but the price we often pay for this efficiency may be bad problem solving, which may be costly. Making judgments by invoking your stereotypes leads even smart people to make dumb decisions. For example, we might use representativeness heuristics to make judgments about possibilities based on our prototypes—what we think is representative of a category. Consider this:

**STOP | THINK | WRITE** If I ask you whether a slim, short stranger who enjoys poetry is more likely to be a truck driver or an Ivy League classics professor, what would you say?

You might be tempted to answer based on your prototypes of truck drivers or professors. But consider the odds. With about 10 Ivy League schools and 4 or so classics professors per school, we have 40 professors. Say 10 are both short and slim, and half of those like poetry—we are left with 5. But there are at least 400,000 truck drivers in the United
States. If only 1 in every 800 of those truck drivers were short, slim, poetry lovers, we have 500 truck drivers who fit the description. With 500 truck drivers versus 5 professors, it is 100 times more likely that our stranger is a truck driver (Myers, 2005).

Teachers and students are busy people, and they often base their decisions on what they have in their minds at the time. When judgments are based on the availability of information in our memories, we are using the availability heuristic. If instances of events come to mind easily, we think they are common occurrences, but that is not necessarily the case; in fact, it is often wrong. People remember vivid stories and quickly come to believe that such events are the norm, but often they are wrong. For example, you may have been surprised to read in Chapter 5 that the average family in poverty has only 2.2 children if you have vivid memories of hearing that “people on welfare just keep having children” or if you saw a powerful film about a large, poor family. Again, data do not support that judgment. But belief perseverance, or the tendency to hold on to our beliefs, even in the face of contradictory evidence, may make us resist change.

The confirmation bias is the tendency to search for information that confirms our ideas and beliefs: this arises from our eagerness to get a good solution. You have often heard the saying “Don’t confuse me with the facts.” This aphorism captures the essence of the confirmation bias. Most people seek evidence that supports their ideas more readily than they search for facts that might refute them (Myers, 2005). For example, once you decide to buy a certain car, you are likely to notice reports about the good features of the car you chose, not the good news about the cars you rejected. Our automatic use of heuristics to make judgments, our eagerness to confirm what we like to believe, and our tendency to explain away failure combine to generate overconfidence. Students usually overestimate how fast they can get their papers written; it typically takes twice as long as they estimate (Buchler, Griffith, & Ross, 1994). In spite of their underestimation of their completion time, they remain overly confident of their next prediction.

The Importance of Flexibility. Functional fixedness, response set, the confirmation bias, and belief perseverance point to the importance of flexibility in understanding problems. If you get started with an inaccurate or inefficient representation of the true problem, it will be difficult—or at least very time-consuming—to reach a solution. Sometimes, it is helpful to “play” with the problem. Ask yourself: “What do I know? What do I need to know to answer this question? Can I look at this problem in other ways?” Try to think conditionally rather than rigidly, and divergently rather than convergently. Ask “What could this be?” instead of “What is it?” (Benjafield, 1992).

If you open your mind to multiple possibilities, you may have what the Gestalt psychologists called an insight. Insight is the sudden reorganization or reconceptualization of a problem that clarifies the problem and suggests a feasible solution. The supervisor described earlier, who suddenly realized that the problem in his building was not slow elevators but impatient, bored tenants, had an insight that allowed him to reach the solution of installing mirrors by the elevators.

Effective Problem Solving: What Do the Experts Do?

Most psychologists agree that effective problem solving is based on an ample store of knowledge about the problem area. In order to solve the matchstick problem, for example, you had to understand Roman and Arabic numbers as well as the concept of square root. You also had to know that the square root of 1 is 1. Let’s take a moment to examine this expert knowledge.

Expert Knowledge. The modern study of expertise began with investigations of chess masters (Simon & Chase, 1973). Results indicated that masters can quickly recognize about 50,000 different arrangements of chess pieces. They can look at one of these patterns for a few seconds and remember where every piece on the board was placed. It is as though they have a “vocabulary” of 50,000 patterns. Michelene Chi (1978) demonstrated that 3rd- through 8th-grade chess experts had a similar ability to remember chess piece arrangements. For all the masters, patterns of pieces are like words. If you were shown any

**Availability heuristic** Judging the likelihood of an event based on what is available in your memory, assuming those easily remembered events are common.

**Belief perseverance** The tendency to hold onto beliefs, even in the face of contradictory evidence.

**Confirmation bias** Seeking information that confirms our choices and beliefs, while disconfirming evidence.

**Insight** Sudden realization of a solution.
Experts have a rich store of declarative, procedural, and conditional knowledge. While basic intelligence is certainly a factor, hard work and practice are also required to become an expert in any given field.

word from your vocabulary store for just a few seconds, you would be able to remember every letter in the word in the right order (assuming you could spell the word).

But a series of letters arranged randomly is hard to remember, as you saw in Chapter 7. An analogous situation holds for chess masters. When chess pieces are placed on a board randomly, masters are no better than average players at remembering the positions of the pieces. The master’s memory is for patterns that make sense or could occur in a game.

A similar phenomenon occurs in other fields. There may be an intuition about how to solve a problem based on recognizing patterns and knowing the “right moves” for those patterns. Experts in physics, for example, organize their knowledge around central principles, whereas beginners organize their smaller amounts of physics knowledge around the specific details stated in the problems (Ericsson, 1999). For instance, when asked to sort physics problems from a textbook in any way they wanted, novices sorted based on superficial features such as the kind of apparatus mentioned—a lever or a pulley—whereas the experts grouped problems according to the underlying physics principle needed to solve the problem, such as Boyle’s or Newton’s laws (Hardiman, Dufresne, & Mestre, 1989).

In addition to representing a problem very quickly, experts know what to do next. They have a large store of productions or condition-action schemas about what action to take in various situations. Thus, the steps of understanding the problem and choosing a solution happen simultaneously and fairly automatically (Ericsson & Charness, 1999). Of course, this means that they must have many, many schemas available. A large part of becoming an expert is simply acquiring a great store of domain knowledge or knowledge that is particular to a field (Alexander, 1992). To do this, you must encounter many different kinds of problems in that field, see problems solved by others, and practice solving many yourself. Some estimates are that it takes 10 years or 10,000 hours of study to become an expert in most fields (Simon, 1995).

Experts’ rich store of knowledge is elaborated and well practiced, so that it is easy to retrieve from long-term memory when needed (Anderson, 1993). Experts can use their extensive knowledge to organize information for easier learning and retrieval. Compared to 4th-graders with little knowledge of soccer, 4th-graders who were soccer experts learned and remembered far more new soccer terms, even though the abilities of the two groups to learn and remember nonsoccer terms were the same. The soccer experts organized and clustered the soccer terms to aid in recall (Schneider & Bjorklund, 1992). Even very young children who are experts on a topic can use strategies to organize their knowledge. To get an example of the use of category knowledge about dinosaurs, I called my nephews, Luc and Geoffrey (4 and 3 years old at the time). They promptly ran down the list of large and small plant- and meat-eating dinosaurs (their organizing categories), from the well-known stegosaurus (large, plant eater) to the less familiar eoceratops (small, meat eater).

With organization comes planning and monitoring. Experts spend more time analyzing problems, drawing diagrams, breaking large problems down into subproblems, and making plans. Whereas a novice might begin immediately—writing equations for a physics problem or drafting the first paragraph of a paper, experts plan out the whole so-
Intuition and often make the task simpler in the process. As they work, experts monitor progress, so time is not lost pursuing dead ends or weak ideas (Schunk, 2004).

Chi, Glaser, and Farr (1988) summarize the superior capabilities of experts. Experts (1) perceive large, meaningful patterns in given information, (2) perform tasks quickly and with few errors, (3) deal with problems at a deeper level, (4) hold more information in working and long-term memories, (5) take a great deal of time to analyze a given problem, and (6) are better at monitoring their performance. When the area of problem solving is fairly well defined, such as chess or physics or computer programming, then these skills of expert problem solvers hold fairly consistently. But when the problem-solving area is less well defined and has fewer clear underlying principles, such as problem solving in economics or psychology, then the differences between experts and novices are not as clear-cut (Alexander, 1992).

Novice Knowledge. Studies of the differences between experts and novices in particular areas have revealed some surprising things about how novices understand and misunderstand a subject. Physics again provides many examples. Most beginners approach physics with a great deal of misinformation, partly because many of their intuitive ideas about the physical world are wrong. Most elementary school children believe that light helps us see by brightening the area around objects. They do not realize that we see an object because the light is reflected by the object to our eyes. This concept does not fit with the everyday experience of turning on a light and "brightening" the dark area. Researchers from the Elementary Science Project at Michigan State University found that even after completing a unit on light in which materials explicitly stated the idea of reflected light and vision, most 5th-grade students—about 78%—continued to cling to their intuitive notions. But when new materials were designed that directly confronted the students' misconceptions, only about 20% of the students failed to understand (Liben, Anderson, & Smith, 1984).

It seems quite important for science teachers to understand their students' intuitive models of basic concepts. If the students' intuitive model includes misconceptions and inaccuracies, then the students are likely to develop inadequate or misleading representations of a problem. (You should note that some researchers don't use the term "misconception," but refer to naive or intuitive conceptions to describe students' beginning knowledge in an area.) In order to learn new information and solve problems, students must sometimes "unlearn" common-sense ideas. Changing your intuitive ideas about concepts involves motivation, too. Pintrich, Marx, and Boyle (1993) suggest that four conditions are necessary for people to change basic concepts: (1) Students have to be dissatisfied with the current concept; that is, their existing concept must be seen as inaccurate, incomplete, or not useful. (2) Students must understand the new concept. (3) The new concept must be plausible—it must fit in with what the students already know. (4) The new concept must be fruitful—it must be seen as useful in solving problems or answering questions.

The Guidelines on the next page give some ideas for helping students become expert problem solvers.

Creativity and Creative Problem Solving

STOP | THINK | WRITE Consider this student. He had severe dyslexia—a learning disability that made reading and writing exceedingly difficult. He described himself as an "underdog." In school, he knew that if the reading assignment would take others an hour, he had to allow two or three hours. He knew that he had to keep a list of all his most frequently misspelled words in order to be able to write at all. He spent hours alone in his room. Would you expect his writing to be creative? Why or why not?

The person in the box above is John Irving, celebrated author of what one critic called "wildly inventive" novels such as The World According to Garp, The Cider House Rules, and A Prayer for Owen Meany (Aramabile, 2001). How do we explain his amazing creativity? What is creativity?
Guidelines: Problem Solving

Ask students if they are sure they understand the problem.

**EXAMPLES:**
1. Can they separate relevant from irrelevant information?
2. Are they aware of the assumptions they are making?
3. Encourage them to visualize the problem by diagramming or drawing it.
4. Ask them to explain the problem to someone else. What would a good solution look like?

Encourage attempts to see the problem from different angles.

**EXAMPLES**
1. Suggest several different possibilities yourself, and then ask students to offer some.
2. Give students practice in taking and defending different points of view on an issue.

Let students do the thinking; don’t just hand them solutions.

**EXAMPLES**
1. Offer individual problems as well as group problems, so that each student has the chance to practice.
2. Give partial credit if students have good reasons for “wrong” solutions to problems.
3. If students are stuck, resist the temptation to give too many clues. Let them think about the problem overnight.

Help students develop systematic ways of considering alternatives.

**EXAMPLES**
1. Think out loud as you solve problems.
2. Ask, “What would happen if?”
3. Keep a list of suggestions.

Teach heuristics.

**EXAMPLES**
1. Use analogies to solve the problem of limited parking in the downtown area. How are other “storage” problems solved?
2. Use the working backward strategy to plan a party.

For more resources on problem solving, see [http://www.hawaii.edu/suremath/home.html](http://www.hawaii.edu/suremath/home.html)

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Defining Creativity

Let’s start with what creativity is not. Here are four myths about creativity (Plucker, Beghetto, & Dow, 2004):

1. **People are born creative.** Actually, years of research show that creativity can be developed, enhanced, and supported by the individual’s or groups’ environment.

2. **Creativity is intertwined with negative qualities.** It is true that some creative people are nonconforming or some may have mental or emotional problems, but many noncreative people do, too. The danger with this myth is that teachers may expect creative students to be troublemakers and treat these students in a biased way (Scott, 1999).

3. **Creativity is a fuzzy, soft construct.** In contrast to seeing a creative person as mentally unbalanced, some people think creative individuals are New Age hippies. Actually, even though creative people may be open to new experiences and be generally nonconforming, they also may be focused, organized, and flexible.

4. **Creativity is enhanced within a group.** It is true that brainstorming in a group can lead to creative ideas, but these group efforts tend to be more creative if individuals brainstorm on their own first.

So what is creativity? **Creativity** is the ability to produce work that is original, but still appropriate and useful (Berk, 2005). Most psychologists agree that there is no such thing as “all-purpose creativity”; people are creative in a particular area, as John Irving was in writing fiction. But to be creative, the “invention” must be intended. An accidental spilling of paint that produces a novel design is not creative unless the artist recognizes the potential of the “accident” or uses the spilling technique intentionally to create new works (Weisberg, 1993). Although we frequently associate the arts with creativity, any subject can be approached in a creative manner.
A definition that combines many aspects of creativity (Plucker et al., 2004) highlights that creativity:

- often involves more than one person,
- happens when people apply their abilities as part of a helpful process in a supportive environment, and
- results in an identifiable product that is new and useful in a particular culture or situation.

What Are the Sources of Creativity?

Researchers have studied cognitive processes, personality factors, motivational patterns, and background experiences to explain creativity (Simonton, 2000). But to truly understand creativity, we must look at the social environment too. Both intrapersonal (cognition, personality) and social factors support creativity (Amabile, 1996; 2001; Simonton, 2000). Teresa Amabile (1996) proposes a three-component model of creativity. Individuals or groups must have:

1. **Domain-relevant skills** including talents and competencies that are valuable for working in the domain. An example would be Michelangelo's skills in shaping stone, developed when he lived with a stonecutter's family as a child.

2. **Creativity-relevant processes** including work habits and personality traits such as a John Irving's habit of working 10-hour days to write and rewrite until he perfected his stories.

3. **Intrinsic task motivation** or a deep curiosity and fascination with the task. This aspect of creativity can be greatly influenced by the social environment (as we will see in Chapter 10), and by supporting autonomy, stimulating curiosity, encouraging fantasy, and providing challenge.

Another social factor that influences creativity is whether the field is ready and willing to acknowledge the creative contribution (Nakamura & Csikszentmihalyi, 2001). History is filled with examples of creative breakthroughs rejected at the time (for example, Galileo's theory of the sun at the center of the solar system) and of rivalries between creators that led each to push the edges of creativity (the friendly and productive rivalry between Picasso and Matisse).

**Creativity and Cognition.** Having a rich store of knowledge in an area is the basis for creativity, but something more is needed. For many problems, that "something more" is the ability to break set—restructuring the problem to see things in a new way, which leads to a sudden insight. Often this happens when a person has struggled with a problem or project, then sets it aside for a while. Some psychologists believe that time away from the problem allows for incubation, a kind of unconscious working through the problem. It is more likely that leaving the problem for a time interrupts rigid ways of thinking so you can restructure your view of the situation (Gleitman, Fridlund, & Reisberg, 1999). So it seems that creativity requires extensive knowledge, flexibility, and the continual reorganizing of ideas. And we saw that motivation, persistence, and social support play important roles in the creative process as well.

**Assessing Creativity**

STOP | THINK | WRITE How many uses can you list for a brick? Take a moment and brainstorm—write down as many as you can. ■

Like the author John Irving, Paul Torrance also had a learning disability; he became interested in educational psychology when he was a high school English teacher (Neumeister & Crandall, 2004). Torrance was known as the "Father of Creativity." He developed two types of creativity tests: verbal and graphic (Torrance, 1972; Torrance & Hall, 1980). In the verbal test, you might be instructed to think up as many uses as possible for a brick (as you did above) or asked how a particular toy might be changed to...
FIGURE 8.6

A Graphic Assessment of the Creativity of an Eight-Year-Old

The titles she gave her drawings from left to right are as follows: "Dracula," "one-eyed monster," "pumpkin," "Hong Kong," "poster," "wheelchair," "earth," "moon," "planet," "movie camera," "sad face," "picture," "stoplight," "beach ball," "the letter O," "car," "glasses.


make it more fun. On the graphic test, you might be given 30 circles and asked to create 30 different drawings, with each drawing including at least one circle. Figure 8.6 shows the creativity of an 8-year-old girl in completing this task.

These tests require divergent thinking, an important component of many conceptions of creativity. Divergent thinking is the ability to propose many different ideas or answers. Convergent thinking is the more common ability to identify only one answer. Responses to all these creativity tasks are scored for originality, fluency, and flexibility, the three aspects of divergent thinking. Originality is usually determined statistically: To be original, a response must be given by fewer than 5 or 10 people out of every 100 who take the test. Fluency is the number of different responses. Flexibility is generally measured by the number of different categories of responses. For instance, if you listed 20 uses of a

Divergent thinking: Coming up with many possible solutions.

Convergent thinking: Narrowing possibilities to a single answer.

Agnes is able to think divergently.


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Chapter 8: Complex Cognitive Processes
Creativity in the Classroom

Today’s and tomorrow’s complex problems require creative solutions. And creativity is important for an individual’s psychological, physical, social, and career success (Plucker et al., 2004). How can teachers promote creative thinking? All too often, in the crush of day-to-day classroom life, teachers stifle creative ideas without realizing what they are doing. Teachers are in an excellent position to encourage or discourage creativity through their acceptance or rejection of the unusual and imaginative. The Guidelines, adapted from Fleith (2000) and Sattler (1992), describe other possibilities for encouraging creativity.

### Guidelines: Encouraging Creativity

1. **Accept and encourage divergent thinking.**
   - **EXA M P L E S:**
     1. During class discussion, ask, “Can anyone suggest a different way of looking at this question?”
     2. Reinforce attempts at unusual solutions to problems, even if the final product is not perfect.
     3. Offer choices in topics for projects or modes of presentation (written, oral, visual or graphic, using technology).

2. **Tolerate dissent.**
   - **EXA M P L E S:**
     1. Ask students to support dissenting opinions.
     2. Make sure nonconforming students receive an equal share of classroom privileges and rewards.

3. **Encourage students to trust their own judgment.**
   - **EXA M P L E S:**
     1. When students ask questions you think they can answer, rephrase or clarify the questions and direct them back to the students.
     2. Give ungraded assignments from time to time.
     3. Emphasize that everyone is capable of creativity in some form.

4. **Recognize creative efforts in each student’s work.** Have a separate grade for originality on some assignments.

5. **Provide time, space, and materials to support creative projects.**
   - **EXA M P L E S:**
     2. Make a well-lighted space available where children can work on projects, leave them, and come back to finish them.
     3. Follow up on memorable occasions (field trips, news events, holidays) with opportunities to draw, write, or make music.

6. **Be a stimulus for creative thinking.**
   - **EXA M P L E S:**
     1. Use a class brainstorming session whenever possible.
     2. Model creative problem solving by suggesting various solutions for class problems.
     3. Encourage students to delay judging a particular suggestion for solving a problem until all the possibilities have been considered.

Brainstorming. In addition to encouraging creativity through everyday interactions with students, teachers can try brainstorming. The basic tenet of brainstorming is to separate the process of creating ideas from the process of evaluating them because evaluation often inhibits creativity (Osborn, 1963). Evaluation, discussion, and criticism are postponed until all possible suggestions have been made. In this way, one idea inspires others; people do not withhold potentially creative solutions out of fear of criticism. John Baer (1997, p. 43) gives these rules for brainstorming:

1. Defer judgment.
2. Avoid ownership of ideas. When people feel that an idea is “theirs,” egos sometimes get in the way of creative thinking. They are likely to be more defensive later when ideas are critiqued, and they are less willing to allow their ideas to be modified.
3. Feel free to “hitchhike” on other ideas. This means that it’s okay to borrow elements from ideas already on the table, or to make slight modifications of ideas already suggested.
4. Encourage wild ideas. Impossible, totally unworkable ideas may lead someone to think of other, more possible, more workable ideas. It’s easier to take a wildly imaginative bad idea and tone it down to fit the constraints of reality than to take a boring bad idea and make it interesting enough to be worth thinking about.

Individuals as well as groups may benefit from brainstorming. In writing this book, for example, I have sometimes found it helpful to list all the different topics that could be covered in a chapter, then leave the list and return to it later to evaluate the ideas.

Take Your Time—and Play! Years ago, Sigmund Freud (1959) linked creativity and play: “Might we not say that every child at play behaves like a creative writer, in that he creates a world of his own, or, rather, rearranges the things of his world in a new way which pleases him? The creative writer does the same as the child at play. He creates a world of phantasy which he takes very seriously—that is, which he invests with large amounts of emotion” (pp. 143–144). There is some evidence that preschool children who spend more time in fantasy and pretend play are more creative. In fact, playing before taking a creativity test resulted in higher scores on the test for the young students in one study (Berk, 2001; Bjorklund, 1989). Teachers can encourage students of all ages to be more reflective—to take time for ideas to grow, develop, and be restructured.

The Big C: Revolutionary Innovation

Ellen Winner (2000) describes the “big-C creativity” of innovation that establishes a new field or revolutionizes an old one. Even child prodigies do not necessarily become adult innovators. Prodigies have mastered well-established domains very early, but innovators change the entire domain. “Individuals who ultimately make creative breakthroughs
tend from their earliest days to be explorers, innovators, and tinkerers. Often this adventurousness is interpreted as insubordination, though more fortunate tinkerers receive from teachers or peers some form of encouragement for their experimentation" (Gardner, 1993a, pp. 32-33). What can parents and teachers do to encourage these potential creators? Winner (2000) lists four dangers to avoid:

1. Avoid pushing so hard that the child’s intrinsic passion to master a field becomes a craving for extrinsic rewards.
2. Avoid pushing so hard that the child later looks back on a missed childhood.
3. Avoid freezing the child into a safe, technically perfect way of performing that has led to lavish rewards.
4. Be aware of the psychological wounds that can follow when the child who can perform perfectly becomes the forgotten adult who can do nothing more than continue to perform perfectly—without ever creating something new.

Finally, teachers and parents can encourage students with outstanding abilities and creative talents to give back to the society that has provided the extra support and resources that they needed. Service learning, discussed in Chapter 11, is one opportunity.

We may not all be revolutionary in our creativity, but we all can be experts in one area—learning.

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**Becoming an Expert Student: Learning Strategies and Study Skills**

**WHAT WOULD YOU SAY?**

As part of your interview, the department chair asks, "Many of our students go on to high-pressure colleges and don’t seem to know how to study when they don’t have daily homework deadlines. How would you help them prepare to handle the heavy work load in those institutions?"

Most teachers will tell you that they want their students to “learn how to learn.” Years of research indicate that using good learning strategies helps students learn and that these strategies can be taught (Hamman, Berthelot, Saia, & Crowley, 2000). But were you taught "how to learn"? Powerful and sophisticated learning strategies and study skills are seldom taught directly until high school or even college, so students have little practice with these powerful strategies. In contrast, early on, students usually discover repetition androte learning on their own, so they have extensive practice with these strategies. And, unfortunately, some teachers think that memorizing is learning (Hofers & Pintrich, 1997; Woolfolk Hoy & Murphy, 2001). This may explain why many students cling to flash cards and memorizing—they don’t know what else to do (Willoughby, Porter, Belkito, & Yeansley, 1999).

As we saw in Chapter 7, the way something is learned in the first place greatly influences how readily we remember and how appropriately we can apply the knowledge later. First, students must be cognitively engaged in order to learn—they have to focus attention on the relevant or important aspects of the material. Second, they have to invest effort, make connections, elaborate, translate, organize, and reorganize in order to think and process deeply—the greater the practice and processing, the stronger the learning. Finally, students must regulate and monitor their own learning—keep track of what is making sense and notice when a new approach is needed. The emphasis today is on helping students develop effective learning strategies and tactics that focus attention and effort, process information deeply, and monitor understanding.

**Learning Strategies and Tactics**

Learning strategies are ideas for accomplishing learning goals, a kind of overall plan of attack. Learning tactics are the specific techniques that make up the plan (Derry, 1989).

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**Connect and Extend to the Research**


This study tested the effectiveness of verbal elaboration (answer why each fact is true), imagery (create a mental picture), and keyword (create a mental picture using the keywords provided) in helping 2nd, 4th, and 6th grade Canadian students remember information from stories. Verbal elaboration worked for all three grades, especially when the students had some prior knowledge related to the stories. Imagery was more helpful than elaborations for older students when the students lacked prior knowledge about the story content, but 2nd graders needed support to use imagery.

**Learning strategies** General plans for approaching learning tasks.

**Learning tactics** Specific techniques for learning, such as using mnemonics or outlining a passage.
Your strategy for learning the material in this chapter might include the tactics of using mnemonics to remember key terms, skimming the chapter to identify the organization, and then writing answers to possible essay questions. Your use of strategies and tactics reflects metacognitive knowledge. Using learning strategies and study skills is related to higher GPAs in high school and staying in school in college (Robbins et al., 2004). Researchers have identified several important principles:

1. Students must be exposed to a number of different strategies, not only general learning strategies but also very specific tactics, such as the graphic strategies described later in this section.
2. Students should be taught conditional knowledge about when, where, and why to use various strategies. Although this may seem obvious, teachers often neglect this step. A strategy is more likely to be maintained and employed if students know when, where, and why to use it.
3. Students may know when and how to use a strategy, but unless they also develop the desire to employ these skills, general learning ability will not improve. Several learning strategy programs include a motivational training component. In Chapter 10 we look more closely at this important issue of motivation.
4. Students should receive direct instruction in schematic knowledge; this is often an important component of strategy training. In order to identify main ideas—a critical skill for a number of learning strategies—you must have an appropriate schema for making sense of the material. It will be difficult to summarize a paragraph about ichthyology, for example, if you don’t know much about fish. Table 8.2 summarizes several tactics for learning declarative (verbal) knowledge and procedural skills (Derry, 1989).

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**TABLE 8.2**

<table>
<thead>
<tr>
<th>Examples of Learning Tactics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tactics for Learning</strong></td>
</tr>
<tr>
<td><strong>Verbal Information</strong></td>
</tr>
<tr>
<td>1. Attention Focusing</td>
</tr>
<tr>
<td>- Making outlines, underlining</td>
</tr>
<tr>
<td>- Looking for headings and topic sentences</td>
</tr>
<tr>
<td>2. Schema Building</td>
</tr>
<tr>
<td>- Story grammars</td>
</tr>
<tr>
<td>- Theory schemas</td>
</tr>
<tr>
<td>- Networking and mapping</td>
</tr>
<tr>
<td>3. Idea Elaboration</td>
</tr>
<tr>
<td>- Self-questioning</td>
</tr>
<tr>
<td>- Imagery</td>
</tr>
<tr>
<td><strong>Tactics for Learning</strong></td>
</tr>
<tr>
<td><strong>Procedural Information</strong></td>
</tr>
<tr>
<td>1. Pattern Learning</td>
</tr>
<tr>
<td>- Hypothesizing</td>
</tr>
<tr>
<td>- Identifying reasons for actions</td>
</tr>
<tr>
<td>2. Self-instruction</td>
</tr>
<tr>
<td>- Comparing own performance to expert model</td>
</tr>
<tr>
<td>3. Practice</td>
</tr>
<tr>
<td>- Part practice</td>
</tr>
<tr>
<td>- Whole practice</td>
</tr>
<tr>
<td><strong>Use When?</strong></td>
</tr>
<tr>
<td>With easy, structured materials; for good readers</td>
</tr>
<tr>
<td>For poorer readers, with more difficult materials</td>
</tr>
<tr>
<td>With poor text structure, goal is to encourage active comprehension</td>
</tr>
<tr>
<td>To understand and remember specific ideas</td>
</tr>
<tr>
<td>To learn attributes of concepts</td>
</tr>
<tr>
<td>To match procedures to situations</td>
</tr>
<tr>
<td>To tune, improve complex skills</td>
</tr>
<tr>
<td>When few specific aspects of a performance need attention</td>
</tr>
<tr>
<td>To maintain and improve skill</td>
</tr>
</tbody>
</table>

Deciding What Is Important. You can see from the first entry in Table 8.2, that learning begins with focusing attention—deciding what is important. But distinguishing the main idea from less important information is not always easy. Often students focus on the "selective details" or the concrete examples, perhaps because they are more interesting (Gardner, Brown, Sanders, & Menke, 1992). You may have had the experience of remembering a joke or an intriguing example from a lecture, but not being clear about the larger point the professor was trying to make. Finding the central idea is especially difficult if you lack prior knowledge in an area and the amount of new information provided is extensive. Teachers can give students practice using signals in texts such as headings, bold words, outlines, or other indicators to identify key concepts and main ideas. Teaching students to summarize material can be helpful, too (Lorch, Lorch, Ritchey, McGovern, & Coleman, 2001).

Summaries. Creating summaries can help students learn, but students have to be taught how to summarize (Byrnes, 1996; Palincsar & Brown, 1984). Jeanne Ormrod (2004) summarizes these suggestions for helping students create summaries. For each summary, ask students to:

- find or write a topic sentence for each paragraph or section,
- identify big ideas that cover several specific points,
- find some supporting information for each big idea, and
- delete any redundant information or unnecessary details.

Begin doing summaries of short, easy, well-organized readings. Introduce longer, less organized, and more difficult passages gradually. Ask students to compare their summaries and discuss what ideas they thought were important and why—what's their evidence?

Two other study strategies that are based on identifying key ideas are underlining texts and taking notes.

STOP | THINK | WRITE How do you make notes as you read? Look back over the past several pages of this chapter. Are my words highlighted yellow or pink? Are there marks or drawings in the margins and if so, do the notes pertain to the chapter or are they grocery lists and e-mail addresses?

Underlining and Highlighting. Do you underline or highlight key phrases in textbooks? Underlining and note taking are probably two of the most commonly but ineffectively used strategies among college students. One common problem is that students underline or highlight too much. It is far better to be selective. In studies that limit how much students can underline—for example, only one sentence per paragraph—learning has improved (Snowman, 1984). In addition to being selective, you also should actively transform the information into your own words as you underline or take notes. Don't rely on the words of the book. Note connections between what you are reading and other things you already know. Draw diagrams to illustrate relationships. Finally, look for organizational patterns in the material and use them to guide your underlining or note taking (Irwin, 1991; Kiewra, 1988).

Taking Notes. As you sit in class, filling your notebook with words or furiously trying to keep up with a lecturer, you may wonder if taking notes makes a difference. It does, if used well:

- Taking notes focuses attention during class and helps encode information so it has a chance of making it to long-term memory. In order to record key ideas in your own words, you have to translate, connect, elaborate, and organize. Even if students don't review notes before a test, taking them in the first place appears to aid learning, especially for those who lack prior knowledge in an area. Of course, if taking notes distracts you from actually listening to and making sense of the lecture, then note taking may not be effective (Kiewra, 1989; Van Meter, Yokoi, & Pressley, 1994).
- Notes provide extended external storage that allows you to return and review. Students who use their notes to study tend to perform better on tests, especially if they
Connect and Extend to Your Teaching/Portfolio

READS is similar to a well-known strategy you might have encountered in school, called PQ4R (Thomas & Robinson, 1972):

- **Preview:** Survey the major topics and sections and set a purpose for reading.
- **Question:** For each major section, write questions that are related to your reading purposes. One way is to turn the headings and subheadings into questions.
- **Read:** At last! The questions you have formulated can be answered through reading.
- **Reflect:** While you are reading, try to think of examples or create images of the material. Elaborate and try to make connections between what you are reading and what you already know.
- **Recite:** After reading each section, sit back and think about your initial purposes and questions. Can you answer the questions without looking at the book?
- **Review:** Effective review incorporates new material more thoroughly into your long-term memory. As study progresses, review should be cumulative, including the sections and chapters you read previously.

Cmaps Tools for concept mapping developed by the Institute for Human Machine Cognition that are connected to many knowledge maps and other resources on the Internet.

READS A five-step reading strategy: Review headings; Examine boldface words; Ask, “What do I expect to learn?”; Do it—Read; Summarize in your own words.

CAPS A strategy that can be used in reading literature: Characters, Aim of story, Problem, Solution.

take many high-quality notes—more is better as long as you are capturing key ideas, concepts, and relationships, not just intriguing details (Kiewra, 1985, 1989; Peverly, Brobst, Graham, & Shaw, 2005).

- Expert students match notes to their anticipated use and modify strategies after tests or assignments; use personal codes to flag material that is unfamiliar or difficult; fill in holes by consulting relevant sources (including other students in the class); record information verbatim only when a verbatim response will be required. In other words, they are strategic about taking and using notes (Van Meter, Yokoi, & Pressley, 1994).
- To help students organize their note taking, some teachers provide matrices or maps. When students are first learning to use these maps, you might fill in some of the spaces for them. If you use maps and matrices with your students, encourage them to exchange their filled-in maps and explain their thinking to each other.

**Visual Tools for Organizing**

To use underlining and note taking effectively, you must identify main ideas. In addition, you must understand the organization of the text or lecture—the connections and relationships among ideas. Some visual strategies have been developed to help students with this key element (Van Meter, 2001). There is some evidence that creating graphic organizers such as maps or charts is more effective than outlining in learning from texts (Robinson, 1998; Robinson & Kiewra, 1995). “Mapping” relationships by noting causal connections, comparison/contrast connections, and examples improved recall. Students should compare “maps” and discuss the differences. Amy’s molecule (Figure 8.2, p. 291) is a hierarchical graphic depiction of the relationships among concepts. There are other ways to visualize organization, such as Venn diagrams, which show how ideas or concepts overlap and tree diagrams, which show how ideas branch off each other. Time lines organize information in sequence and are useful in classes such as history or geography.

An exciting possibility is Cmaps, developed by researchers at the Institute for Human Machine Cognition (IHMC). Joseph Novak, a senior researcher at the institute, developed concept mapping in the 1970s at Cornell University (Amy’s Molecule came from his work). Now, Novak and the IHMC have developed tools to create concept maps that are available for downloading at no cost. My students at Ohio State use these tools—one even planned his dissertation and organized all the reading for his doctoral examinations using them. Computer Cmaps can be linked to the Internet and students in different classrooms and schools all over the world can collaborate on them. The home page of the Cmap tools is shown in Figure 8.7.

**Reading Strategies**

As we saw above, effective learning strategies and tactics should help students focus attention, invest effort (elaborate, organize, summarize, connect, translate) so they process information deeply, and monitor their understanding. There are a number of strategies that support these processes in reading. Many use mnemonics to help students remember the steps involved. For example, one strategy for any grade above later elementary is READS:

- **R** Review headings and subheadings.
- **E** Examine boldface words.
- **A** Ask, “What do I expect to learn?”
- **D** Do it—Read;
- **S** Summarize in your own words. (Friend & Burack, 1996)

A strategy that can be used in reading literature is CAPS:

- **C** Who are the characters?
- **A** What is the aim of the story?
- **P** What problem happens?
- **S** How is the problem solved?
Anderson (1995a) suggests several reasons why strategies such as CAPS or READS are effective. First, following the steps makes students more aware of the organization of a given chapter. How often have you skipped reading headings entirely and thus missed major clues about the way the information was organized? Next, these steps require students to study the chapter in sections instead of trying to learn all the information at once. This makes use of distributed practice. Creating and answering questions about the material forces students to process the information more deeply and with greater elaboration (Doctrow, Wittrock, & Marks, 1978; Hamilton, 1985).

Many of the cooperating teachers I work with use a strategy called KWL to guide reading and inquiry in general. This general frame can be used with most grade levels. The steps are:

K What do I already know about this subject?
W What do I want to know?
L At the end of the reading or inquiry, what have I learned?

No matter what strategies you use, students have to be taught how to use them. Direct teaching, explanation, modeling, and practice with feedback are necessary. Direct teaching of learning and reading strategies is especially important for students with learning challenges and students whose first language is not English. Marilyn Friend and William Buronk (2002) describe how one teacher used modeling and discussion to teach the KWL strategy. After reviewing the steps, the teacher models an example and a nonexample of using KWL to learn about "crayons."

Connect and Extend to Your Teaching/Portfolio
Add Figure 8.7, “Cmaps,” to your file of Teaching Resources.

Connect and Extend to the Research

KWL A strategy to guide reading and inquiry: Before—What do I already know? What do I want to know? After—What have I learned?
One cooperative learning strategy used by many teachers to guide reading and inquiry is called KWL: What do I know? What do I want to know? What have I learned?

Teacher: What do we do now that we have a passage assigned to read? First, I brainstorm, which means I try to think of anything I already know about the topic and write it down.

The teacher writes on the board or overhead known qualities of crayons, such as “made of wax,” “come in many colors,” “can be sharpened,” “several different brands.”

Teacher: I then take this information I already know and put it into categories, like “what crayons are made of” and “crayon colors.” Next, I write down any questions I would like to have answered during my reading, such as “Who invented crayons? When were they invented? How are crayons made? Where are they made?” At this point, I’m ready to read, so I read the passage on crayons. Now I must write down what I learned from this passage. I must include any information that answers the questions I wrote down before I read and any additional information. For example, I learned that colored crayons were first made in the United States in 1903 by Edwin Binney and E. Harold Smith. I also learned that the Crayola Company owns the company that made the original magic markers. Last, I must organize this information into a map so I can see the different main points and any supporting points.

At this point, the teacher draws a map on the chalkboard or overhead.

Teacher: Let’s talk about the steps I used and what I did before and after I read the passage.

A class discussion follows.

Teacher: Now I’m going to read the passage again, and I want you to evaluate my textbook reading skills based on the KWL Plus strategy we’ve learned.

The teacher then proceeds to demonstrate the strategy incorrectly.

Teacher: The passage is about crayons. Well, how much can there really be to know about crayons besides there are hundreds of colors and they always seem to break in the middle? Crayons are for little kids, and I’m in junior high so I don’t need to know that much about them. I’ll just skim the passage and go ahead and answer the question. Okay, how well did I use the strategy steps?

The class discusses the teacher’s inappropriate use of the strategy. Notice how the teacher provides both an example and a nonexample—good concept teaching.

The Guidelines provide a summary of ideas about studying.

Applying Learning Strategies

Assuming students have a repertoire of powerful learning strategies, will they use them? Several conditions must be met (Ormrod, 2004). First, of course, the learning task must be appropriate. Why would students use more complex learning strategies when the task set by the teacher is to “learn and return” the exact words of the text or lecture? With these
Guidelines: Becoming an Expert Student

Make sure you have the necessary declarative knowledge (facts, concepts, ideas) to understand new information.

EXAMPLES
1. Keep definitions of key vocabulary available as you study.
2. Review required facts and concepts before attempting new material.

Find out what type of test the teacher will give (essay, short answer), and study the material with that in mind.

EXAMPLES
1. For a test with detailed questions, practice writing answers to possible questions.
2. For a multiple-choice test, use mnemonics to remember definitions of key terms.

Make sure you are familiar with the organization of the materials to be learned.

EXAMPLES
1. Preview the headings, introductions, topic sentences, and summaries of the text.
2. Be alert for words and phrases that signal relationships, such as on the other hand, because, first, second, however, since.

Know your own cognitive skills and use them deliberately.

EXAMPLES
1. Use examples and analogies to relate new material to something you care about and understand well, such as sports, hobbies, or films.
2. If one study technique is not working, try another—the goal is to stay involved, not to use any particular strategy.

Study the right information in the right way.

EXAMPLES
1. Be sure you know exactly what topics and readings the test will cover.
2. Spend your time on the important, difficult, and unfamiliar material that will be required for the test or assignment.
3. Keep a list of the parts of the text that give you trouble and spend more time on those pages.
4. Process the important information thoroughly by using mnemonics, forming images, creating examples, answering questions, making notes in your own words, and elaborating on the text. Do not try to memorize the author's words—use your own.

Monitor your own comprehension.

EXAMPLES
1. Use questioning to check your understanding.
2. When reading speed slows down, decide if the information in the passage is important. If it is not, note the problem so you can reread or get help to understand. If it is not important, ignore it.
3. Check your understanding by working with a friend and quizzing one another.

For more resources on studying, see:
http://www.ncce.vt.edu/study/studyhelp.html
http://www.dmmn.edu/student/fom/acad/strat/

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Valuing Learning. The second condition for using sophisticated strategies is that students must care about learning and understanding. They must have goals that can be reached using effective strategies (Zimmerman & Schunk, 2001). I was reminded of this one semester when I enthusiastically shared with my educational psychology class an article from the newspaper, USA Today, about study skills. The gist of the article was that students should continually revise and rewrite their notes from a course, so that by the end, all their understanding could be captured in one or two pages. Of course, the majority of the knowledge at that point would be reorganized and connected well with other knowledge. “See,” I told the class, “these ideas are real—not just trapped in texts. They can help you study smarter.”

Connect and Extend to Other Chapters
The guidelines for study skills apply to everyone who wishes to become an expert learner and involve the metacognitive abilities and executive control processes discussed in Chapter 7. See Chapter 7 for a discussion of declarative, procedural, and conditional knowledge.
in college.” After a heated discussion, one of the best students said in exasperation, “I’m carrying 18 hours—I don’t have time to learn this stuff.” She did not believe that her goal—to survive the 18 hours—could be reached by using time-consuming study strategies.

**Effort and Efficacy.** The student above also was concerned about effort. The third condition for applying learning strategies is that students must believe the effort and investment required to apply the strategies are reasonable, given the likely return (Winne, 2001). And of course, students must believe that they are capable of using the strategies; that is, they must have self-efficacy for using the strategies to learn the material in question (Schunk, 2004). This is related to another condition. Students must have a base of knowledge and/or experience in the area. No learning strategies will help students accomplish tasks that are completely beyond their current understandings.

**Epistemological Beliefs.** Finally, what students believe about knowledge and learning (their epistemological beliefs) will influence the kinds of strategies that they use.

**STOP THINK WRITE** How would you answer these questions taken from Chan & Sachs (2001)?

1. The most important thing in learning math is to: (a) remember what the teacher has taught you, (b) practice lots of problems, (c) understand the problems you work on.

2. The most important thing you can do when trying to do science is (a) faithfully do the work the teacher tells you, (b) try to see how the explanation makes sense, (c) try to remember everything you are supposed to know.

3. If you wanted to know everything there is about something, say animals, how long would you have to study it? (a) less than a year if you study hard, (b) about one or two years, (c) forever.

4. As you learn more and more about something (a) the questions get more and more complex, (b) the questions get easier and easier, (c) the questions all get answered.

Using questions like those above, researchers have identified several dimensions of epistemological beliefs (Chan & Sachs, 2001; Schommer, 1997; Schommer-Aikins, 2002; Schraw & Olafson, 2002). For example:

- **Structure of Knowledge:** Is knowledge in a field a simple set of facts or a complex structure of concepts and relationships?
- **Stability/Certainty of Knowledge:** Is knowledge fixed or evolving over time?
- **Ability to Learn:** Is the ability to learn fixed (based on innate ability) or changeable?
- **Speed of Learning:** Can we gain knowledge quickly or does it take time to develop knowledge?
- **Nature of Learning:** Does learning mean memorizing facts passed down from authorities and keeping the facts isolated, or developing your own integrated understandings?

Students’ beliefs about knowing and learning affect their use of learning strategies. For example, if you believe that knowledge should be gained quickly, you are likely to try one or two quick strategies (read the text once, spend 2 minutes trying to solve the word problem) and then stop. If you believe that learning means developing integrated understandings, you will process the material more deeply, connect to existing knowledge, create your own examples, or draw diagrams, and generally elaborate the information to make it your own (Hofer & Pintrich, 1997; Kardish & Howell, 2000). In one study, elementary school students (grades 4 and 6), who believed that learning is understanding, processed science texts more deeply than students who believed that learning is reproducing facts (Chan & Sachs, 2001). The questions about learning in the Stop/Think/Write box above were used in that study to assess the students’ beliefs. The answers associated with a belief in complex, evolving, knowledge that takes time to understand and grows from active learning are 1c, 2b, 3c, and 4a.

Here is an important question: What is the purpose of all that studying if you never use the knowledge—if you never transfer it to new situations?
Teaching for Transfer

STOP | THINK | WRITE  Think back for a moment to a class in one of your high-
school subjects that you have not studied in college. Imagine the teacher, the room, the
textbook. Now remember what you actually learned in class. If it was a science class,
what were some of the formulas you learned? Oxidation reduction? Boyle’s law?

If you are like most of us, you may remember that you learned these things, but you will
not be quite sure exactly what you learned. Were those hours wasted? These questions are
about the transfer of learning. We turn to that important topic next. Let’s begin with a
definition of transfer.

Whenever something previously learned influences current learning or when solving
an earlier problem affects how you solve a new problem, transfer has occurred (Mayer
& Wittrock, 1996). Erik De Corte (2003) calls transfer “the productive use of cognitive
tools and motivations” (p. 142). This meaning of transfer emphasizes doing something
new (productive), not just reproducing a previous application of the tools. If students
learn a mathematical principle in one class and use it to solve a physics problem days or
weeks later in another class, then transfer has taken place. However, the effect of past
learning on present learning is not always positive. Functional fixedness and response set
(described earlier in this chapter) are examples of negative transfer because they are at-
ttempts to apply familiar but inappropriate strategies to a new situation.

The Many Views of Transfer

Transfer has been a focus of research in educational psychology for over 100 years. After
all, the productive use of knowledge, skills, and motivations across a lifetime is a funda-
mental goal of education (De Corte, 2003). Early work focused on specific transfer of
skills and the general transfer of mental discipline gained from studying rigorous subjects
such as Latin or mathematics. But in 1924, E. L. Thorndike demonstrated that there was
no mental discipline benefit from learning Latin. Learning Latin just helped you learn
more Latin. So, thanks to Thorndike, you were not required to take Latin in high school.
Other researchers looked at positive and negative transfer, such as the appropriate and in-
appropriate uses of heuristics in solving problems.

More recently, researchers distinguish between the automatic, direct use of skills
such as reading or writing in everyday applications versus the extraordinary transfer of
knowledge and strategies to arrive at creative solutions to problems (Bereiter, 1995; Brans-
ford & Schwartz, 1999; Salomon & Perkins, 1989). Gabriel Salomon and David Perkins
(1989) describe these two kinds of transfer, termed low-road and high-road transfer. Low-
road transfer “involves the spontaneous, automatic transfer of highly practiced skills, with
little need for reflective thinking” (p. 118). The key to low-road transfer is practicing a skill
often, in a variety of situations, until your performance becomes automatic. So if you
worked one summer for a temporary secretarial service and were sent to many different
offices to work on all kinds of computers, by the end of the summer you probably
would be able to handle most machines easily. Your practice with many machines would let you
transfer your skill automatically to a new situation. Bransford and Schwartz (1999) refer
to this kind of transfer as direct-application transfer.

High-road transfer, on the other hand, involves consciously applying abstract knowl-
edge or strategies learned in one situation to a different situation. This can happen in one
of two ways. First, you may learn a principle or a strategy, intending to use it in the
future-forward-reaching transfer. For example, if you plan to apply what you learn in
anatomy class this semester to work in a life-drawing course you will take next semester,
you may search for principles about human proportions, muscle definition, and so on.
Second, when you are faced with a problem, you may look back on what you have
learned in other situations to help you in this new one-backward-reaching transfer.
Analogical thinking is an example of this kind of transfer. You search for other, related
situations that might provide clues to the current problem. Bransford and Schwartz
(1999) consider this kind of high-road transfer to be preparation for future learning.

Transfer  Influence of previously learned material on new material.
Low-road transfer  Spontaneous and automatic transfer of highly practiced skills.
High-road transfer  Application of abstract knowledge learned in one situation to a different situation.
### TABLE 8.3

<table>
<thead>
<tr>
<th>Kinds of Transfer</th>
<th>Low-Road Transfer (Direct-Application)</th>
<th>High-Road Transfer (Preparation for Future Learning)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>Automatic transfer of highly practiced skill</td>
<td>Conscious application of abstract knowledge to a new situation</td>
</tr>
<tr>
<td>Key Conditions</td>
<td>Extensive practice</td>
<td>Productive use of cognitive tools and motivations</td>
</tr>
<tr>
<td></td>
<td>Variety of settings and conditions</td>
<td>Mindful focus on abstracting a principle, main idea, or procedure that can be used in many situations</td>
</tr>
<tr>
<td></td>
<td>Overlearning to automaticity</td>
<td>Learning in powerful teaching-learning environments</td>
</tr>
<tr>
<td>Examples</td>
<td>Driving many different cars</td>
<td>Applying KWL or READS strategies</td>
</tr>
<tr>
<td></td>
<td>Finding your gate in an airport</td>
<td>Applying procedures from math in designing a page layout for the school newspaper</td>
</tr>
</tbody>
</table>

The key to high-road transfer is mindful abstraction, or the deliberate identification of a principle, main idea, strategy, or procedure that is not tied to a specific problem or situation, but could apply to many. Such an abstraction becomes part of your metacognitive knowledge, available to guide future learning and problem solving. Bransford and Schwartz (1999) add another key—a resource-rich environment that supports productive, appropriate transfer. Table 8.3 summarizes the types of transfer.

### Teaching for Positive Transfer

Years of research and experience show that students will master new knowledge, problem-solving procedures, and learning strategies, but usually they will not use them unless prompted or guided. For example, studies of real-world mathematics show that people do not always apply math procedures learned in school to solve practical problems in their homes or grocery stores (Lave, 1988; Lave & Wenger, 1991). This happens because learning is situated; that is, learning happens in specific situations. We learn solutions to particular problems, not general, all-purpose solutions that can fit any problem. Because knowledge is learned as a tool to solve particular problems, we may not realize that the knowledge is relevant when we encounter a problem that seems different, at least on the surface (Driscoll, 2005; Singley & Anderson, 1989). How can you make sure your students will use what they learn, even when situations change?

**What Is Worth Learning?** First, you must answer the question “What is worth learning?” The learning of basic skills such as reading, writing, computing, cooperating, and speaking will definitely transfer to other situations, because these skills are necessary for later work both in and out of school—writing job applications, reading novels, paying bills, working on a team, locating and evaluating health care services, among others. All later learning depends on positive transfer of these basics to new situations.

Teachers must also be aware of what the future is likely to hold for their students, both as a group and as individuals. What will society require of them as adults? As a child growing up in Texas in the 1950s and 1960s, I studied nothing about computers, even though my father was a computer systems analyst; yet now I spend hours at my Mac. Computer programming and word processing were not part of my high-school curriculum, but I learned to use a slide rule. Now, calculators and computers have made this skill obsolete. My mom encouraged me to take advanced math and physics instead of typing in high school. Those were great classes, but I struggle with typing every day at my computer—who knew? Undoubtedly, changes as extreme and unpredictable as these await the stu-
dents you will teach. For this reason, the general transfer of principles, attitudes, learning strategies, motivations, and problem solving will be just as important for your students as the specific transfer of basic skills.

How Can Teachers Help? For basic skills, greater transfer can also be ensured by over-learning, practicing a skill past the point of mastery. Many of the basic facts students learn in elementary school, such as the multiplication tables, are traditionally overlearned. Overlearning helps students retrieve the information quickly and automatically when it is needed. See the Stories of Learning/Tributes to Teaching feature for an example of active engagement and overlearning.

For higher-level transfer, students must first learn and understand. Students will be more likely to transfer knowledge to new situations if they have been actively involved in the learning process. They must be encouraged to form abstractions that they will apply later. Erik De Corte (2003) believes that teachers support transfer, the productive use of cognitive tools and motivations, when they create powerful teaching-learning environments using these design principles:

- The environments should support constructive learning processes in all students.
- The environments should encourage the development of student self-regulation, so that teachers gradually give over more and more responsibilities to the students.
- Learning should involve interaction and collaboration.
- Learners should deal with problems that have personal meaning for them, problems like they will face in the future.
- The classroom culture should encourage students to become aware of and develop their cognitive and motivational processes. In order to be productive users of these tools, students must know about and value them.

The next three chapters delve in depth about how to support constructive learning, motivation, self-regulation, collaboration, and self-awareness in all students.

There is one last kind of transfer that is especially important for students—the transfer of the learning strategies we encountered in the previous section. Learning strategies and tactics are meant to be applied across a wide range of situations, but this often does not happen, as you will see below.

STORIES OF LEARNING

ESME CODELL, a first-year teacher in an urban school, describes how she helped her students learn and succeed in a real-world task that was especially difficult for them—public speaking.

May 12

Storyteller’s Workshop is going well. I got a small grant. After school a couple of times a week, I train a dozen children to give dramatic performances of folktales. I specifically picked children who are particularly shy or challenged in reading or speaking. We went on a field trip to see a professional storyteller, and they all own copies of the books they are going to perform. For the past six weeks, I’ve been training them, modeling for them, and—to some extent—pressuring them. I had them go “on tour” to other classes during school hours to help them gain confidence and to get feedback. We are hosting a school-wide storytelling festival in less than two weeks.

Maurissa didn’t want to perform for the fourth grade. Her dark skin paled to the color of ash; she was so afraid. I sent her with Ruben and Latoya, to watch and support her. She begged me not to make her go. Secretly, I wondered if she would throw up. But I literally pushed her out the door anyway and told her not to return until the mission was accomplished, that I knew she could do it. She came back fifteen minutes later—I should say lept in—smiling broadly, her color back to normal.

“I did it! I did a beautiful job.” She burst out laughing and crying at the same time, and we embraced.

Rochelle, another shy girl I sent out, returned breathing heavily. “You were right! The kids did join in on the repeated lines.” I’m so proud of their successes. I know in the face of the wide world these are small victories, but sometimes a little song is sweet to hear, even if an orchestra is more accomplished.

Stages of Transfer for Strategies. Sometimes students simply don't understand that a particular strategy applies in new situations or they don't know how to adapt it to fit. As we saw above, they may think the strategy takes too much time (Schunk, 2004).

Gary Phye (1992, 2001; Phye & Sanders, 1994) suggests we think of the transfer of learning strategies as a tool to be used in a "mindful" way to solve academic problems. He describes three stages in developing strategic transfer. In the acquisition phase, students should not only receive instruction about a strategy and how to use it, but they should also rehearse the strategy and practice being aware of when and how they are using it. In the retention phase, more practice with feedback helps students hone their strategy use. In the transfer phase, the teacher should provide new problems that can be solved with the same strategy, even though the problems appear different on the surface. To enhance motivation, point out to students how using the strategy will help them solve many problems and accomplish different tasks. These steps help build both procedural and conditional knowledge—how to use the strategy as well as when and why.

Diversity and Convergences in Complex Cognitive Processes

This chapter has covered quite a bit of territory, partly because the cognitive perspective has so many implications for instruction. Although they are varied, you can see that most of the cognitive ideas for teaching concepts, creative problem-solving skills, and learning strategies emphasize the role of the student's prior knowledge and the need for active, mindful learning.

Diversity

Concept learning, problem solving, and strategy-learning processes may be similar for all students, but the prior knowledge, beliefs, and skills they bring to the classroom are bound to vary, based on their experience and culture. For example, The Chen and his colleagues (2004) wondered if college students might use familiar folk tales—one kind of cultural knowledge—as analogies to solve problems. That is just what happened. Chinese students were better at solving a problem of weighing a statue because the problem was similar to their folk tale about how to weigh an elephant (by water displacement). American students were better at solving a problem of finding the way out of a cave (involving a trail), by using an analogy to Hansel and Gretel, a common American folk tale. In another study in Australia, Volet (1999) found that some culturally based knowledge and motivation of Asian students—such as high achievement motivation, a deep processing and effortful approach to learning, and a recognition of the benefits of collaboration—
**Guidelines:** Promoting Transfer

Keep families informed about their child's curriculum so they can support learning.

**Examples:**
1. At the beginning of units or major projects, send a letter summarizing the key goals, a few of the major assignments, and some common problems students have in learning the material for that unit.
2. Ask parents for suggestions about how their child's interests could be connected to the curriculum topics.
3. Invite parents to school for an evening of "strategy learning." Have the students teach their family members one of the strategies they have learned in school.

Give families ideas for how they might encourage their children to practice, extend, or apply learning from school.

**Examples:**
1. To extend writing, ask parents to encourage their children to write letters or e-mail to companies or civic organizations asking for information or free products. Provide a shell letter form for structure and ideas and include addresses of companies that provide free samples or information.
2. Ask family members to include their children in some projects that require measurement, halving or doubling recipes, or estimating costs.
3. Suggest that students work with grandparents to do a family memory book. Combine historical research and writing.

Show connections between learning in school and life outside school.

**Examples:**
1. Ask families to talk about and show how they use the skills their children are learning in their jobs, hobbies, or community involvement projects.
2. Ask family members to come to class to demonstrate how they use reading, writing, science, math, or other knowledge in their work.

Make families partners in practicing learning strategies.

**Examples:**
1. Focus on one learning tactic at a time—ask families to simply remind their children to use a particular tactic with homework that week.
2. Develop a lending library of books and videotapes to teach families about learning strategies.

For more information on promoting transfer see:
http://www.kidsource.com/education/motivation.lang.learn.html#2

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transferred well to Western-oriented schools. Other culturally based beliefs, such as valuing rote memorization or solitary learning might cause conflicts with the expectations of some schools. For example, we saw in Chapter 5 that the native Hawaiian style of interacting was seen as interrupting by non-Hawaiian teachers until the teachers learned more about the family communication styles of their students.

**Creativity and Diversity.** Even though creativity has been studied for centuries, as Dean Simonton said, "Psychologists still have a long way to go before they come anywhere close to understanding creativity in women and minorities" (2000, p. 156). The focus of creativity research and writing over the years has been white males. Patterns of creativity in other groups are complex—sometimes matching and sometimes diverging from patterns found in traditional research. The *Family and Community Partnerships Guidelines* give ideas for enlisting the support of families in encouraging transfer.

In another connection between creativity and culture, research suggests that being on the outside of mainstream society, being bilingual, or being exposed to other cultures might encourage creativity (Simonton, 1999, 2000). In fact, true innovators often break rules. "Creators have a desire to shake things up. They are restless, rebellious, and dissatisfied with the status quo" (Winner, 2000, p. 167).

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**Convergences**

As you have seen throughout this chapter, in the beginning, as students learn problem solving or try to transfer cognitive tools to new situations, there is a tendency to focus on...
Connect and Extend to Your Teaching/Portfolio

Use the Family and Community Partnerships Guidelines to brainstorm ideas for family involvement in helping your students "take learning home."

Learning and Teaching about Concepts (pp. 286–294)

Distinguish between prototypes and exemplars. Concepts are categories used to group similar events, ideas, people, or objects. A prototype is the best representative of its category. For instance, the best representative of the "birds" category for many Americans might be a robin. Exemplars are actual memories of specific birds and so on that we use to compare with an item in question to see if that item belongs in the same category as our exemplar. We probably learn concepts from prototypes or exemplars of the category, understand in terms of our schematic knowledge, and then refine concepts through our additional experience of relevant and irrelevant features.

What are the four elements needed in concept teaching? Lessons about concepts include four basic components: concept examples (along with nonexamples), relevant and irrelevant attributes, name, and definition. The concept attainment model is one approach to teaching concepts that asks students to form hypotheses about why particular examples are members of a category and what that category (concept) might be.

What are the key characteristics of Bruner's discovery learning? In discovery learning, the teacher presents examples and the students work with the examples until they discover the interrelationships—the subject's structure. Bruner believes that classroom learning should take place through inductive reasoning, that is, by using specific examples to formulate a general principle.

What are the stages of Ausubel's expository teaching? Ausubel believes that learning should progress deductively: from the general to the specific, or from the rule or principle to examples. After presenting an advance organizer, the next step in a lesson using Ausubel's approach is to present content in terms of basic similarities and differences, using specific examples. Finally, when all the material has been presented, ask students to discuss how the examples can be used to expand on the original advance organizer.

How can you teach concepts through analogies? By identifying known information that relates to a new concept, teachers and students can map the analogies between the known and the new, then summarize an understanding of the new concept by explaining the similarities and differences between the known and the new concepts.

- Concept A general category of ideas, objects, people, or experiences whose members share certain properties.
- Defining attributes Distinctive features shared by members of a category.
- Prototype Best representative of a category.
- Exemplar A specific example of a given category that is used to classify an item.
- Undergeneralization Exclusion of some true members from a category; limiting a concept.
- Overgeneralization Inclusion of nonmembers in a category; overextending a concept.
- Concept mapping Student's diagram of his or her understanding of a concept.
- Discovery learning Bruner's approach, in which students work on their own to discover basic principles.
- Inductive reasoning Formulating general principles based on knowledge of examples and details.
- Intuitive thinking Making imaginative leaps to correct perceptions or workable solutions.
- Guided discovery An adaptation of discovery learning, in which the teacher provides some direction.
Expository teaching Ausubel’s method—teachers present material in a complete, organized form, moving from broadest to more specific concepts.

Deductive reasoning Drawing conclusions by applying rules or principles: logically moving from a general rule or principle to a specific solution.

Meaningful verbal learning Focused and organized relationships among ideas and verbal information.

Advance organizer Statement of inclusive concepts to introduce and sum up material that follows.

Analogical instruction Teaching new concepts by making connections (analogies) with information that the student already understands.

**Problem Solving** (pp. 294–305)

What are the steps in the general problem-solving process? Problem solving is both general and domain-specific. The five stages of problem solving are contained in the acronym IDEAL: Identify problems and opportunities; Define goals and represent the problem; Explore possible strategies; Anticipate outcomes and Act; Look back and I.earn.

Why is the representation stage of problem solving so important? To represent the problem accurately, you must understand both the whole problem and its discrete elements. Schema training may improve this ability. The problem-solving process follows entirely different paths, depending on what representation and goal are chosen. If your representation of the problem suggests an immediate solution, the task is done; the new problem is recognized as a “disguised” version of an old problem with a clear solution. But if there is no existing way of solving the problem or if the activated schema fails, then students must search for a solution. The application of algorithms and heuristics—such as means-ends analysis, analogical thinking, working backward, and verbalization—may help students solve problems.

Describe factors that can interfere with problem solving. Factors that hinder problem solving include functional fixedness or rigidity (response set). These disallow the flexibility needed to represent problems accurately and to have insight into solutions. Also, as we make decisions and judgments, we may overlook important information because we base judgments on what seems representative of a category (representativeness heuristic) or what is available in memory (availability heuristic), then pay attention only to information that confirms our choices (confirmation bias) so that we hold onto beliefs, even in the face of contradictory evidence (belief perseverance).

What are the differences between expert and novice knowledge in a given area? Expert problem solvers have a rich store of declarative, procedural, and conditional knowledge. They organize this knowledge around general principles or patterns that apply to large classes of problems. They work faster, remember relevant information, and monitor their progress better than novices.

How do misconceptions interfere with learning? If the students’ intuitive model includes misconceptions and inaccuracies, then the students are likely to develop inadequate or misleading representations of a problem. In order to learn new information and solve problems, students must sometimes “unlearn” common-sense ideas.

Problem Any situation in which you are trying to reach some goal and must find a means to do so.

Problem solving Creating new solutions for problems.

Schema-driven problem solving Recognizing a problem as a “disguised” version of an old problem for which one already has a solution.

Algorithm Step-by-step procedure for solving a problem; prescription for solutions.

Heuristic General strategy used in attempting to solve problems.

Means-ends analysis Heuristic in which a goal is divided into subgoals.

Working-backward strategy Heuristic in which one starts with the goal and moves backward to solve the problem.

Analogical thinking Heuristic in which one limits the search for solutions to situations that are similar to the one at hand.

Verbalization Putting your problem-solving plan and its logic into words.

Functional fixedness Inability to use objects or tools in a new way.

Response set Rigidity; tendency to respond in the most familiar way.

Representativeness heuristic Judging the likelihood of an event based on how well the events match your prototypes—what you think is representative of a category.

Availability heuristic Judging the likelihood of an event based on what is available in your memory, assuming those easily remembered events are common.

Belief perseverance The tendency to hold onto beliefs, even in the face of contradictory evidence.

Confirmation bias Seeking information that confirms our choices and beliefs, while disconfirming evidence.

Insight Sudden realization of a solution.

**Creativity and Creative Problem Solving** (pp. 305–311)

What are some myths about creativity? These four statements are completely or partly wrong. Creativity is determined at birth. Creativity comes with negative personality traits. Creative people are disorganized hippie types. Working in a group enhances creativity. The facts are: Creativity can be developed. A few but not all creative people are nonconforming or have emotional problems. Many creative people are focused, organized, and part of the mainstream. Finally, groups can limit as well as enhance creativity.

What is creativity and how is it assessed? Creativity is a process that involves independently restructuring problems to see things in new, imaginative ways. Creativity is difficult to measure, but tests of divergent thinking can assess originality, fluency, and flexibility. Originality is usually determined statistically. To be original, a response must be given by fewer than 5 or 10 people out of every 100 who take the test. Fluency is the number of different responses. The number of different categories of responses measures flexibility. Teachers can encourage creativity by providing opportunities for play, using brainstorming techniques, and accepting divergent ideas.
What can teachers do to support creativity in the classroom? Teachers can encourage creativity in their interactions with students by accepting unusual, imaginative answers, modeling divergent thinking, using brainstorming, and tolerating dissent.

Creativity Imaginative, original thinking or problem solving.
Restructuring Conceiving of a problem in a new or different way.
Divergent thinking Coming up with many possible solutions.
Convergent thinking Narrowing possibilities to a single answer.
Brainstorming Generating ideas without stopping to evaluate them.

Becoming an Expert Student: Learning Strategies and Study Skills (pp. 311–318)

Distinguish between learning strategies and tactics. Learning strategies are ideas for accomplishing learning goals, a kind of overall plan of attack. Learning tactics are the specific techniques that make up the plan. A strategy for learning might include several tactics such as mnemonics to remember key terms, skimming to identify the organization, and then writing answers to possible essay questions. Use of strategies and tactics reflects metacognitive knowledge.

What key functions do learning strategies play? Learning strategies help students become cognitively engaged—focus attention on the relevant or important aspects of the material. Second, they encourage students to invest effort, make connections, elaborate, translate, organize, and reorganize in order to think and process deeply—the greater the practice and processing, the stronger the learning. Finally, strategies help students regulate and monitor their own learning—keep track of what is making sense and notice when a new approach is needed.

Describe some procedures for developing learning strategies. Expose students to a number of different strategies, not only general learning strategies but also very specific tactics, such as the graphic strategies. Teach conditional knowledge about when, where, and why to use various strategies. Develop motivation to use the strategies and tactics by showing students how their learning and performance can be improved. Provide direct in instruction in content knowledge needed to use the strategies.

When will students apply learning strategies? If they have appropriate strategies, students will apply them if they are faced with a task that requires good strategies, value doing well on that task, think the effort to apply the strategies will be worthwhile, and believe that they can succeed using the strategies. Also, to apply deep processing strategies, students must assume that knowledge is complex and takes time to learn and that learning requires their own active efforts.

Learning strategies General plans for approaching learning tasks.
Learning tactics Specific techniques for learning, such as using mnemonics or outlining a passage.
Cmaps Tools for concept mapping developed by the Institute for Human Machine Cognition that are connected to many knowledge maps and other resources on the Internet.
READS A five-step reading strategy: Review headings; Examine boldface words; Ask, "What do I expect to learn?"; Do it—Read; Summarize in your own words.
CAPS A strategy that can be used in reading literature: Characters, Aim of story, Problem, Solution.
KWL A strategy to guide reading and inquiry: Before—What do I already know? What do I want to know? After—What have I learned?
Epistemological beliefs Beliefs about the structure, stability, and certainty of knowledge and how knowledge is best learned.

Teaching for Transfer (pp. 319–322)

What is transfer? Transfer occurs when a rule, fact, or skill learned in one situation is applied in another situation; for example, applying rules of punctuation to write a job application letter. Transfer also involves applying to new problems the principles learned in other, often dissimilar situations.

Distinguish between low-road and high-road transfer. Transfer involving spontaneity and automaticity in familiar situations has been called low-road transfer. High-road transfer involves reflection and conscious application of abstract knowledge to new situations. Learning environments should support active constructive learning, self-regulation, collaboration, and awareness of cognitive tools and motivational processes. In addition, students should deal with problems that have meaning in their lives. In addition, teachers can help students transfer learning strategies by teaching strategies directly, providing practice with feedback, and then expanding the application of the strategies to new and unfamiliar situations.

Transfer Influence of previously learned material on new material: the productive (not reproductive) uses of cognitive tools and motivations.
Low-road transfer Spontaneous and automatic transfer of highly practiced skills.
High-road transfer Application of abstract knowledge learned in one situation to a different situation.
Overlearning Practicing a skill past the point of mastery.

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  - Lesson Planning
In this chapter's Teachers' Casebook, you recognized that your students need good study skills to do well in their classes now and those in the future. But how can you help them develop these skills and still learn all the material demanded by your district curriculum guides? Here is how some practicing teachers responded to the challenge—PRAXIS II often includes questions on learning strategies and study skills.

What Would They Do?

Here is how some practicing teachers would help their students develop study skills as they teach content:

Vivian M. LaColla Special Education Teacher, Naumkeag Road Elementary School, Peabody, MA

The majority of children need to be taught "how to study." Teaching skills to help them study and manage time should be started with smaller reading assignments and spelling tests that begin as early as first grade. Incorporating strategies taught from SQRW (Survey, Question, Read, Write) and PQW (Print, Question, Write, Evaluate) with other skills helps students develop these skills toward reading, understanding, and remembering longer assignments. Using reading, underlining, use of index cards, and mnemonics are essential skills that are applied during proficiency or achievement tests. To help students manage time with larger projects, it is important to teach students how to break down each assignment into smaller tasks and apply reasonable due dates. This can be done as a whole group while prioritizing and creating checklists for each task. Developing organizational skills, using calendars, schedules, and checklists at the early grades is essential.

Deborah P. Reed
Darby Woods Elementary School, Galloway, OH

Thomas J. Reed
Beechcroft High School, Columbus, OH

In order to help students develop effective study strategies and organizational skills, model exemplary processes and provide multiple opportunities for practice. To model expository processes, show long passages of text on an overhead and articulate the processes that identify the main ideas, the ways to organize information, and the connections to one's own experiences. As students gain competencies in their own study skills, allow them to model their processes, choices, and connections to the rest of the class. To provide opportunities for practice, establish checkpoints for students assigned to large projects. Breaking the project down into smaller segments over the course of a week, require students to complete specific tasks related to the project, and provide timely, content-specific feedback on everything students submit. If at any time a student is falling behind, employ a variety of interventions to help the student get back on track.

Debbie Youngblood Sixth Grade Wellness and Physical Education Teacher, Hilliard City Schools, Hilliard, OH

I would begin by modeling the necessary organizational skills—State standards, benchmarks, and indicators for each content area would be posted in the classroom, and daily learning objectives for each subject would be written on the chalkboard, allowing students to focus on what is most important. Students would be provided with a list of required organizational school supplies, including an age-appropriate daily planner that goes into core content areas. Any binders, dividers, pencils, pens, and highlighters. Class time would be utilized during the first week of school to work the students through the organization of their binders with a section for each subject. Assignments would be recorded daily in their planners and an assignment log for each subject. By working backwards from the due dates for each assignment, we would map out and record timelines for successful completion of each one. I would divide large projects into smaller assignments with frequent completion checkpoints along the way.

Randall B. Sampson Assistant-Principal, Senior High School, Revere, MA

Students' demonstration of their ability to synthesize and apply many subject areas should be included in the students' final learning process. According to research and professional agreements, students are expected to develop skills in written synthesis. It would recommend that teachers provide students with measurable goals, a comprehensive rubric, and feedback on mastery orientation.

W. Sean Keatley Former Assistant Principal, Gallipoli Elementary School, Canton, MS

Consider how material is being delivered in the classroom setting: Are the various learning styles of students being addressed? Kinesthetic, auditory, visual? If not, then look at your lesson plans to see how you can alter them to make them more memorable for students. Most local colleges offer courses in study skills. Consider asking someone from the local community college or university to visit your class and present information on study skills. If they are not able to come, ask for relevant information so that you can present it to the class yourself. Don't forget to use the parents as a resource. Phone calls or conferences with parents will provide the ultimate follow-up to ensure individual success.

What Would They Do?