TABLE 9.2 • **Teaching Strategies for Improving Students' Metacognitive Knowledge and Skills**

- These eight guidelines taken from Pressley and Woloshyn (1995) should help you in teaching any metacognitive strategy.
- Teach a few strategies at a time, intensively and extensively as part of the ongoing curriculum.
- Model and explain new strategies.
- If parts of the strategy were not understood, model again and re-explain strategies in ways that are sensitive to those confusing or misunderstood aspects of strategy use.
- Explain to students where and when to use the strategy.
- Provide plenty of practice, using strategies for as many appropriate tasks as possible.
- Encourage students to monitor how they are doing when they are using strategies.
- Increase students' motivation to use strategies by heightening their awareness that they are acquiring valuable skills—skills that are at the heart of competent functioning.
- Emphasize reflective processing rather than speedy processing; do everything possible to eliminate high anxiety in students; encourage students to shield themselves from distractions so they can attend to academic tasks.

For a list of strategies and links to resources about them, see http://pedagogy.merlot.org/TeachingStrategies.html.
Source: Adapted from Pressley, M., & Woloshyn, V. (1995). Cognitive Strategy Instruction That Really Improves Children's Academic Performance. *Cambridge, MA: Brookline Books, p. 18.*

N "Note a LINCing story." Create a story that bridges the vocabulary word with the known word.
C "Create a LINCing picture." Draw a picture that represents the story.
S "Self-test." Check their learning of the vocabulary word by reciting all the parts of their LINCS.

After a year, the grade 6 students who had participated in the Learning Strategies Curriculum performed significantly better on reading comprehension and strategy use, but there were no differences for grade 9 students. It is possible that reading strategy instruction is most effective in elementary and early middle school when students are learning how to learn through reading (Cantrell, Almasi, Carter, Rintamaa, & Madden, 2010).

Of course, you have to do more than just tell students about the strategy—you have to teach it. Michael Pressley, formerly of the University of Western Ontario, and his colleague Vera Woloshyn at Brock University (1995) developed the Cognitive Strategies Model as a guide for teaching students to improve their metacognitive strategies. Table 9.2 describes the steps in teaching these strategies.

PROBLEM SOLVING

STOP & THINK You're interviewing with the district superintendent for a position as a school psychologist. The superintendent 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—Anita 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. She got the answer and the job, but what a tense moment that was. It seems the superintendent was interested in her ability to solve problems—under pressure!

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

A **problem** has an initial state (the current situation), a goal (the desired outcome), and a path for reaching the goal (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, 2012). Also, problems can range from *well structured* to *ill structured*, depending on how clear-cut the goals are and how much structure is provided for solving them. Most arithmetic problems are well structured, but finding the right university major is ill structured. Ill-structured problems have many different solutions and paths to solutions. 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, 2006). Some psychologists suggest that most human learning involves problem solving (Anderson, 1993).

There is 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. General problem-solving strategies usually include the steps of *identifying* the problem, *setting goals*, *exploring* possible solutions and consequences, *acting,* and finally *evaluating* the outcome.

Actually, there is evidence for the value of both general and specific strategies. In their research with grades 4 and 5 students, Steven Hecht and Kevin Vargi (2010) found that both domain-specific and general factors affected performance on problems involving fractions. The influences were specific conceptual knowledge about fractions and the general information processing skill of attentive classroom behaviour. Another study with children in grade 3 found that both specific arithmetic knowledge and general attention-focusing skills were related to arithmetic problem solving (Fuchs et al., 2006). Finally, Robert Kail and Lynda Hall (1999) found that both domain-specific arithmetic knowledge and general information processing skills, including reading and information processing time, were related to success in solving word problems.

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).

A key first step in any problem solving—general or specific—is identifying that a problem exists (and perhaps treating the problem as an opportunity).

Identifying: Problem Finding

Watch
Identifying: Problem Finding

Problem identification is not always straightforward. We are reminded of 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 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.

Even though problem identification is a critical first step, research indicates that people often "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 carefully considering the nature of the problem (Bruning, Schraw, & Norby, 2011). 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?

Problem solving Creating new solutions for problems.

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 design 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 *activate the right schema* to understand the whole problem.

STOP & THINK 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 colour (adapted from Sternberg & Davidson, 1982)? •

FOCUSING ATTENTION ON WHAT IS RELEVANT. Representing the problem often requires finding the relevant information 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 different colours of socks in the drawer, you will have to remove only three socks before two of them match.

UNDERSTANDING THE WORDS. The second task in representing a problem is understanding the meaning of the words, sentences, and factual information in the problem. So problem solving requires comprehending the language and relations in the problem. In math word problems, it also involves assigning mathematical operators (addition, division, etc.) to relations among numbers (Jitendra et al., 2009; Lee, Ng, & Ng, 2009). All this makes a demand on working memory. For example, a major 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 grade 1 student:

> **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).

A common difficulty for older students is understanding that ratio and proportion problems are based on multiplicative relations, not additive relations (Jitendra et al., 2009). So to solve

$$2 : 14 = ? : 35$$

many students subtract to find the difference between 2 and 14 (14 – 2 = 12) and then subtract 12 from 35 to get 23, giving them the (wrong) answer

$$2 : 14 = 23 : 35$$

The real question is about the *proportional* relationship between 2 and 14. How many times larger than 2 is 14? The answer: 7 times larger. Then the real question is "35 is 7 times larger than what number?" The answer is 5 ($7 \times 5 = 35$). So

$$2 : 14 = 5 : 35$$

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—the next challenge (Van de Walle, Kary, & Bay-Williams, 2010).

UNDERSTANDING THE WHOLE PROBLEM. The third task in representing a problem is to assemble 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 Two train stations are 50 miles apart. At 2 p.m. one Saturday afternoon, two trains start toward each other, one from each station. Just as the trains pull 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 (activate a distance schema) 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 particular information and sets up expectations for what the right answer should look like. For example, if you use a distance schema in the above problem, the right answer looks like adding up many small distance calculations (Kalyuga, Chandler, Tuovinen, & Sweller, 2001; Reimann & Chi, 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 to "make" it fit 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 the presence of the word *more* in a problem that really requires *subtraction* (Fenton, 2007; Resnick, 1981). Figure 9.3 gives examples of different ways students might represent a simple mathematics problem. Exposure to different ways of representing and solving problems helps develop mathematical understanding (Star & Rittle-Johnson, 2009).

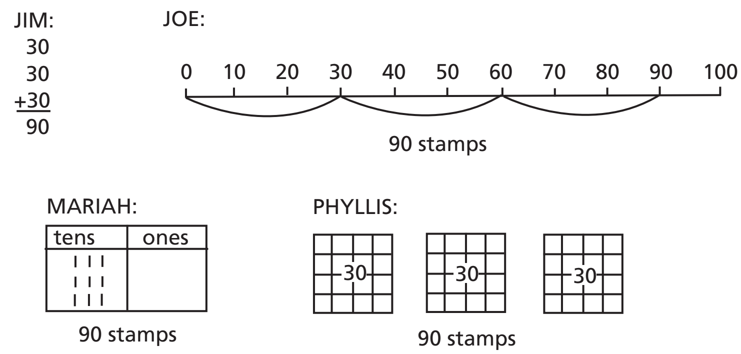
How can students who lack a good base of knowledge improve their translation and schema selection? To answer this question, we usually have to move to area-specific problem-solving strategies because schemas are specific to content areas.

TRANSLATION AND SCHEMA TRAINING: DIRECT INSTRUCTION IN SCHEMAS. For students with little knowledge in an area, teachers can begin by directly teaching the

FIGURE 9.3

FOUR DIFFERENT WAYS TO REPRESENT A PROBLEM

A teacher asks, "How many wildlife stamps will Jane need to fill her book if there are three pages and each page holds 30 stamps?" The teacher gives the students supplies such as a squared paper, number lines, and place-value frames and encourages them to think of as many ways as possible to solve the problem. Here are four different solutions, based on four different but correct representations.



Source: Riedesel, C. A, Schwartz, J. E. (1999). *Essentials of Elementary Mathematics*, 2nd Edition. Reprinted by permission of Pearson Education, Inc., Upper Saddle River, NJ.

necessary schema using demonstration, modelling, and "think-alouds." As we just saw, ratio/proportion problems like the following are a big challenge for many students.

> Ernesto and Dawn worked separately on their social studies projects this weekend. The ratio of the number of hours Ernesto spent on the project to the number of hours Dawn spent on the project was 2:3. If Ernesto spent 16 hours on the project, how many hours did Dawn spend on the project? (Jitendra et al., 2009, p. 257)

The teacher used a "think-aloud" to focus students on the key schema for solving this problem, so she said, "**First,** I figure this is a ratio problem, because it compared the number of hours that Ernesto worked **to** the number of hours Dawn worked. This is a **part-part ratio** that tells about a **multiplicative relationship** (2:3) between the hours Ernesto and Dawn worked." The teacher went on to think aloud, "**Next**, I represented the information. . . . **Finally**, I used the equivalent fractions strategy and . . . ." The think-aloud demonstration can be followed by providing students with many *worked examples*. In mathematics and physics it appears that in the *early stages* of learning, students benefit from seeing many different kinds of example problems worked out correctly for them (Moreno, Ozogul, & Reisslein, 2011). But before we explore worked examples in the next section, a caution is in order. Students with advanced knowledge improve when they solve new problems, not when they focus on already worked-out examples. Worked examples can actually interfere with the learning of more expert students. This has been called the *expert reversal effect* because what works for experts is the *reverse* of what works for beginners (Kalyuga & Renkl, 2010).

TRANSLATION AND SCHEMA TRAINING: WORKED EXAMPLES. Worked examples reflect all the stages of problem solving—identifying the problem, setting goals, exploring solutions, solving the problem, and finally evaluating the outcome (Schworm & Renkl, 2007; van Gog, Paas, & Sweller, 2010). Worked examples are useful in many subject areas. Adrienne Lee and Laura Hutchinson (1998) found that undergraduate students learned more when they were provided with 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. Silke Schworm and Alexander Renkl (2007) used video examples to help student teachers learn how to make convincing arguments for or against a position.

Why are examples effective? Part of the answer is in *cognitive load theory*, discussed in the previous chapter. When students lack specific knowledge in domains—for example, fractions or proportions—they try to solve the problems using general strategies such as looking for key words or applying rote procedures. But these approaches put great strain on working memory—too much to "keep in mind" at once overloads memory. In contrast, worked examples chunk some of the steps, provide cues and feedback, focus attention on relevant information, and make fewer demands on memory, so the students can use cognitive resources to understand instead of searching randomly for solutions (Wittwer & Renkl, 2010).

WORKED OUT EXAMPLES Students benefit from seeing many different kinds of example problems worked out correctly for them, especially when they show an expert problem solver's thinking at critical steps.

To get the most benefit from worked examples, however, students have to actively engage—just "looking over" the examples is not enough. This is not too surprising when you think about what supports learning and memory. You need to pay attention, process deeply, and connect with what you already know. Students should explain the examples to themselves. This *self-explanation* component is a critical part of making learning from worked examples active, not passive. Examples of self-explanation strategies include trying to predict the next step in a solution, then checking to see if you are right or trying to identify an underlying principle that explains how to solve the problem. In their study with student teachers, Schworm and Renkl (2007) embedded prompts that required the student teachers to think about and explain elements of the arguments they saw on the tape, such as, "Which argumentative elements does this sequence contain? How is it related to Kirsten's statement?" (p. 289). Students have to be mentally engaged in making sense of the examples—and self-explanation is one key to engagement (Atkinson & Renkl, 2007; Wittwer & Renkl, 2010).

Another way to use worked examples is to have students compare examples that reach a right answer, but are worked out in different ways. What is the same about each solution? What is different? Why? (Rittle-Johnson & Star, 2007) Also, worked-out examples should deal with one source of information at a time rather than having students move between text passages, graphs, tables, and so on. The cognitive load will be too heavy for beginners if they have to integrate many sources of information to make sense of the worked examples (Marcus, Cooper, & Sweller, 1996).

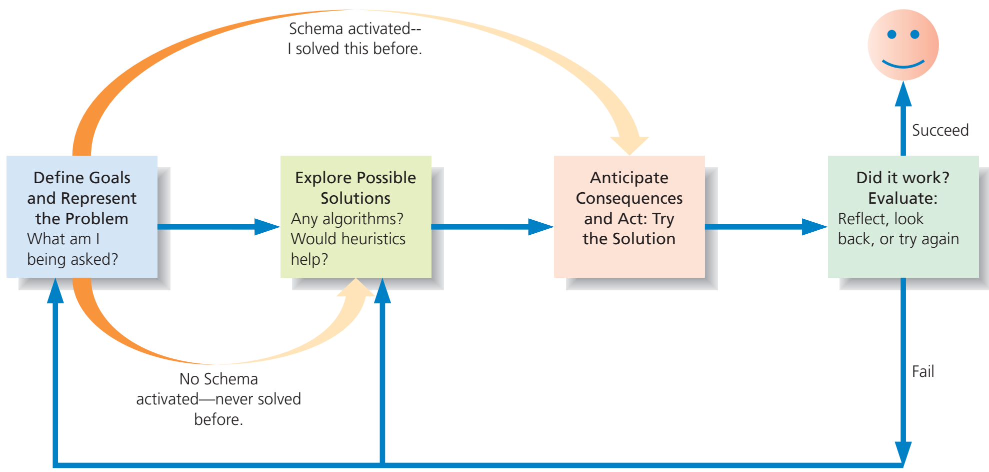
Worked examples can serve as analogies or models for solving new problems. But beware. Without explanations and coaching, novices may remember the surface features of a worked example or case instead of the deeper meaning or the structure. It is the meaning or structure, not the surface similarities, that helps in solving new, analogous problems (Gentner, Lowenstein, & Thompson, 2003). We have heard students complain that the test preparation problems in their math classes were about boats and river currents, but the test asked about airplanes and 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 problem-solving schema that captures the common structure, not the surface features, of the cases (Gentner, Loewenstein, & Thompson, 2003).

How else might students develop the schemas they will need to represent problems in a particular subject area? Mayer (1983) has recommended giving students practice in the following: (1) recognizing and categorizing a variety of problem types;

FIGURE 9.4

THE PROBLEM-SOLVING PROCESS

There are two paths to a solution. In the first, the correct schema is activated and the solution is apparent—the new problem is an old one in disguise. But if no schema works, searching and testing may provide a path to a solution.



(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 9.4. 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 knew how to solve. Seeing through a disguised problem to recognize it as one that can be solved using an "old" schema is called **schema-driven problem solving**. In terms of Figure 9.4, you can use the schema-activated route and proceed directly to a solution.

But what if you have no existing way of solving the problem or your activated schema fails? Time to search for a solution!

Exploring Possible Solution Strategies

In conducting your search for a solution, you have available two general kinds of procedures: algorithmic and heuristic. Both of these are forms of procedural knowledge (Schraw, 2006).

ALGORITHMS. An **algorithm** is a step-by-step procedure for achieving a goal. It usually is domain specific, meaning it is tied to a particular subject area. In solving a problem, if you choose an appropriate algorithm (e.g., to find the arithmetic mean, you add all the scores, then divide by the number of scores) and implement it properly, a right answer is guaranteed. Unfortunately, students often apply algorithms unsystematically, trying out one first, and then another. They may even happen on the right answer, but not understand how they got there, or they may forget the steps they used to find the answer. 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. But many problems cannot be solved by algorithms. What then?

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.

HEURISTICS. A **heuristic** is a general strategy that might lead to the right answer (Schoenfeld, 2011). Because many of life's problems (careers, relationships, etc.) are not straightforward and have ill-defined problem statements and no apparent algorithms, 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 loom as 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.

Some problems lend themselves to a **working-backward strategy**. Using this heuristic, you begin at the goal and work 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 four weeks, I should have a first draft finished by the eleventh, and that means I better stop searching for new references and start writing by . . .").

Another useful heuristic is **analogical thinking** (Copi, 1961; Gentner, Loewenstein, & Thompson, 2003). This heuristic 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. Take note, however—to use analogies effectively, you must focus on meaning and not surface similarities. So focusing on bats' appearance would not have helped to solve the submarine problem.

The possible analogies students bring to the classroom are bound to vary based on their experience and culture. For example, Zhe Chen and his colleagues (Chen, 2004) wondered if postsecondary 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). North American students were better at solving a problem of finding the way out of a cave (leaving a trail), by using an analogy to Hansel and Gretel, a common folk tale.

Putting your problem-solving plan into words and giving reasons for selecting it can lead to successful problem solving (Lee & Hutchinson, 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

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 genetically modified 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 results by checking for evidence that confirms or contradicts your solution. Many people tend to stop working before they reach 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 × 21, the answer should be around 200, because 10 × 20 is 200. A student who reaches an answer of 2311

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.

or 32 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.

Factors That Hinder Problem Solving

Sometimes problem solving requires looking at things in new ways. People may miss out on a good solution because they fixate 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:

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.

V = VII   VI = XI   XII = VII   VI = II

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 Raudsepp & Haugh, 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 $\sqrt{1} = 1$, which is simply the symbolic way of saying that the square root of 1 equals 1. Recently, a creative reader of this text emailed some other solutions. Jamaal Allan, then a master's student, pointed out that you could use any of the matchsticks to change the = sign to ≠. Then, the last example would be V ≠ II, 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). Bill Wetta offered another solution that used both Arabic and Roman numerals. You can move one matchstick to make the first V an X. Then VI = II becomes XI = II, or eleven (in Roman numerals) equals 11 (in Arabic numerals). Just this morning, another creative approach was submitted by Ray Partlow, an educational psychology student. He noted, "Simply remove a matchstick from the V from the left-hand side, and place it directly on top of the I, getting II = II." Covering one matchstick with another opens up a whole new set of possibilities! Can you come up with any other solutions? Be creative!

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 can be costly. Making judgments by invoking stereotypes leads even smart people to make dumb decisions. For example, we might use a **representativeness heuristic** to make judgments about possibilities based on our prototypes—what we think is representative of a category. Consider this:

> 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. Depending how you count, there are about 200 universities and colleges in Canada with perhaps an average of two or so classics professors per school. So, we have 400 professors. Say about 20% are both short and slim—that's 80; and half of those like poetry—we are left with 40. Suppose there are 200 000 truck drivers in Canada. If only one in every 1000 of those truck drivers were short, slim, poetry lovers, we have 200 truck drivers who fit the description. With 40 professors versus 200 truck drivers, it's five times more likely that our stranger is a truck driver (Myers, 2005).

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

Response set Rigidity; the 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 the category.

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. For example, you may have been surprised to read in Chapter 4 that accelerating gifted students' pace through the grades does not undermine their social development. Data may not support a 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. 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 are overconfident about how fast they can get their papers written; it typically takes twice as long as they estimate (Buehler, Griffin, & Ross, 1994). In spite of their underestimation of their completion time, they remain overly confident of their next prediction.

The *Guidelines* give some ideas for helping students become good problem solvers.

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 on to beliefs, even in the face of contradictory evidence.

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

Expert Knowledge and Problem Solving

Most psychologists agree that effective problem solving is based on having an ample store of knowledge about the problem area (Schoenfeld, 2011). 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.

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 practise.
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.

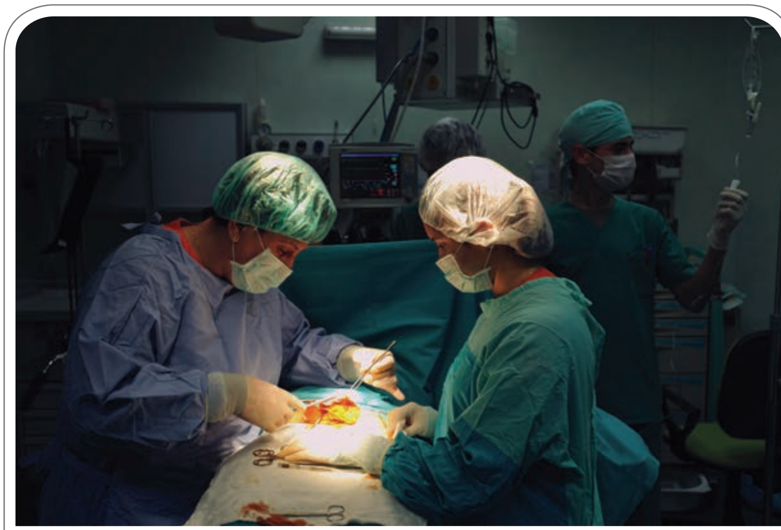
For more resources on problem solving, see www.hawaii.edu/suremath/home.html.

KNOWING WHAT IS IMPORTANT. Experts know where to focus their attention. For example, knowledgeable baseball fans pay attention to the moves of the shortstop to learn if the pitcher will throw a fastball, curveball, or slider. But those with little knowledge about baseball may never see the movements of the shortstop, unless the ball is hit toward that part of the field (Bruning, Schraw, & Norby, 2011). In general, experts know what to pay attention to when judging a performance or product such as an Olympic high dive or a prize-winning chocolate cake. To nonexperts, most good dives or cakes look about the same, unless of course they "flop"!

MEMORY FOR PATTERNS AND ORGANIZATION. 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 grade 3 through 8 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 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 9. 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 (e.g., Boyle's or Newton's laws), whereas beginners organize their smaller amounts of physics knowledge around the specific details stated in the problems (e.g., levers or pulleys) (Ericsson, 1999; Fenton, 2007).

PROCEDURAL KNOWLEDGE. In addition to representing a problem very quickly, experts know what to do next and are able do it. They have a large store of *productions* or IF-THEN 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, observe others solving problems, and practise solving many yourself. Some estimates are that it takes 10 years or 10 000 hours of deliberate, focused, sustained practice to become an expert in most fields (Ericsson, 2011; Ericsson & Charness, 1994; Simon, 1995). Experts' rich store of knowledge is elaborated and well practised, so that it is easy to retrieve from long-term memory when needed (Anderson, 1993).



EXPERT KNOWLEDGE A large part of becoming an expert is simply acquiring a great store of *domain knowledge*, or knowledge that is particular to a field. This surgeon has likely invested years of deliberate, focused, sustained practice to become an expert.

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 solution 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, 2012).

So what can we conclude? Experts (1) know where to focus their attention, (2) perceive large, meaningful patterns in given information and are not confused by surface features and details, (3) hold more information in working and long-term memories, in part because they have organized the information into meaningful chunks and procedures, (4) take a great deal of time to analyze a given problem, (5) have automatic procedures for accomplishing pieces of the problem, and (6) are better at monitoring their performance. When the area of problem solving is well defined, such as chess or physics, 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).

Creativity and Creative Problem Solving

STOP & THINK 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 of 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 described 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* (Amabile, 2001). How do we explain his amazing creativity? What is creativity?

Defining Creativity

Creativity is the ability to produce work that is original, but still appropriate and useful (Plucker, Beghetto, & Dow, 2004). 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 she 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.

Assessing Creativity

STOP & THINK 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 had a learning disability. He became interested in educational psychology when he was a high school English teacher (Neumeister & Cramond, 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 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 9.5 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—three aspects of divergent thinking. *Originality* is usually determined statistically. To be original, a response must be given by fewer than five or 10 people out of every 100 who take the test. *Fluency*

Creativity Imaginative, original thinking or problem solving.

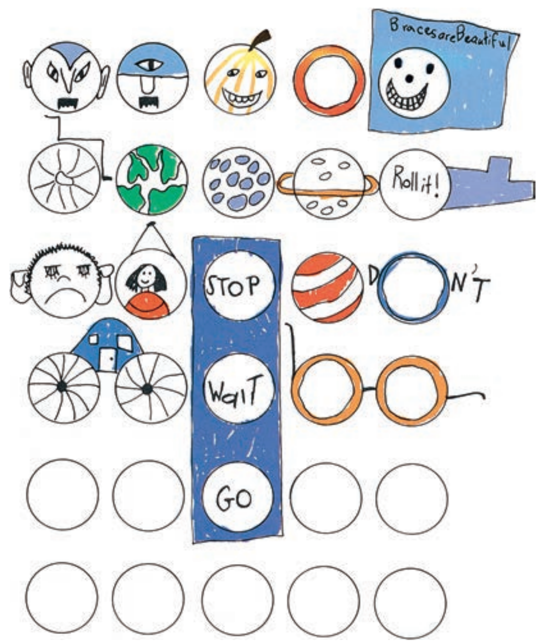
Divergent thinking Coming up with many possible solutions.

Convergent thinking Narrowing possibilities to a single answer.

FIGURE 9.5

A GRAPHIC ASSESSMENT OF THE CREATIVITY OF AN 8-YEAR-OLD

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



Source: Torrance, E. P. (1986, 2000). A Graphic Assessment of the Creativity of an Eight-Year-Old. The Torrance Test of Creative Thinking. *Reprinted with permission of Scholastic Testing Service, Inc., Bensonville, IL.*

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 brick, but each was to build something, your fluency score might be high, but your flexibility score would be low. Of the three measures, fluency—the number of responses—is the best predictor of divergent thinking, but there is more to real-life creativity than divergent thinking (Plucker, Beghetto, & Dow, 2004).

A few possible indicators of creativity in your students are curiosity, concentration, adaptability, high energy, humour (sometimes bizarre), independence, playfulness, non-conformity, risk taking, attraction to the complex and mysterious, willingness to fantasize and daydream, intolerance for boredom, and inventiveness (Sattler & Hoge, 2006).

What Are the Sources of Creativity?

Researchers have studied cognitive processes, personality factors, motivational patterns, and background experiences to explain creativity (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, such as 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 John Irving's habit of working 10-hour days to write and rewrite 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 teachers and parents who support autonomy, stimulate curiosity, encourage fantasy, and provide challenge.

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 see things in a new way—**restructuring** the problem, which leads to a sudden **insight**, a realization of a solution. Often this happens when a person has struggled with a problem or project, and then sets it aside for a while. Some psychologists believe that time away allows for *incubation*, a kind of unconscious working through the problem. Actually, it is more complex than that. Incubation seems to help more on divergent thinking tasks than on verbal or visual tasks. Also, incubation is more helpful when a longer preparation period precedes the individual's setting the problem aside (Sio & Ormerod, 2009). Leaving the problem for a time probably interrupts rigid ways of thinking so you can restructure your view of the situation and think more divergently (Gleitman, Fridlund, & Reisberg, 1999). Creativity requires extensive knowledge, flexibility, and the continual reorganizing of ideas. And we saw that motivation, persistence, and social support play important roles as well.

SOCIAL ACCEPTANCE OF CREATIVITY History is filled with examples of creative breakthroughs rejected in their time (for example, Galileo's theory of the sun as the centre of the solar system). Is today's society ready to welcome creative contributions in the field of alternative energies?

Paul Whitfield © Dorling Kindersley

CREATIVITY AND DIVERSITY. As Dean Simonton said, even with years of research on creativity, "Psychologists still have a long way to go before they come anywhere close to understanding creativity in women and minorities" (2000, p. 156). Thus far, white males have been the focus of creativity research and writing over the years. However, patterns of creativity in other groups are complex—sometimes matching and sometimes diverging from patterns found in traditional research.

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, 2000). In fact, true innovators often break rules. "Creators have a desire to shake things up" (Winner, 2000, p. 167). In addition, even for those who are not outside the mainstream, it appears that participation in multicultural experiences fosters creativity. Angela Ka-Yee Leung and her colleagues (Leung & Chiu, 2008; Maddux, Leung, Chui, & Galinsky, 2009) reviewed theory and research, including experimental studies that exposed participants to information and images about other cultures. The researchers concluded that multicultural experiences support both creative processes, such as retrieving novel or unconventional ideas from memory, and creative performance, such as generating insightful solutions to problems. These effects are especially strong when people open themselves up to divergent ideas, and when the situation does not emphasize finding quick, firm answers. Multicultural individuals are particularly willing to consider and build on unfamiliar ideas, entertain conflicting alternatives, and make unlikely connections between ideas (Leung & Chiu, 2010; Maddux & Galinsky, 2009). So even though your students may not be able to travel to Tibet or Turkey, they still could become more creative problem solvers if they learned about different cultures.

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, Beghetto, & Dow, 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 and Hoge (2006), describe other possibilities for encouraging creativity.

Restructuring Conceiving of a problem in a new or different way.

Insight Sudden realization of a solution.

GUIDELINES

Encouraging Creativity

Accept and encourage divergent thinking.
Examples
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).

Tolerate dissent.
Examples
1. Ask students to support dissenting opinions.
2. Make sure nonconforming students receive an equal share of classroom privileges and rewards.

Encourage students to trust their own judgment.
Examples
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.

Emphasize that everyone is capable of creativity in some form.
Examples
1. Avoid describing the feats of great artists or inventors as if they were superhuman accomplishments.
2. Recognize creative efforts in each student's work. Have a separate grade for originality on some assignments.

Provide time, space, and materials to support creative projects.
Examples
1. Collect "found" materials for collages and creations—buttons, stones, shells, paper, fabric, beads, seeds, drawing tools, clay—try flea markets and friends for donations. Have mirrors and pictures for drawing faces.
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.

Be a stimulus for creative thinking.
Examples
1. Use class brainstorming sessions whenever possible.
2. Model creative problem solving by suggesting unusual solutions for class problems.
3. Encourage students to delay judging a particular suggestion for solving a problem until all the possibilities have been considered.

For more ideas, see http://eric.ed.gov/?id=ED389474.

In addition to encouraging creativity through everyday interactions with students, teachers can try brainstorming. The basic tenet of **brainstorming** is to generate ideas without evaluating them, because evaluation often inhibits generation (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 it is to take a boring bad idea and make it interesting enough to be worth thinking about.

Brainstorming Generating ideas without stopping to evaluate them.

Individuals as well as groups may benefit from brainstorming. In writing this text, for example, we 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.

The Big C: Revolutionary Innovation

Ellen Winner (2000) describes the "big-C creativity," or 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, 1993, 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—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—critical thinking.

Critical Thinking and Argumentation

Many educational psychologists believe that good thinking can and should be developed in school. One way to develop students' thinking is to create a *culture of thinking* in your classrooms (Perkins, Jay, & Tishman, 1993). This means that there is a spirit of inquisitiveness and critical thinking, a respect for reasoning and creativity, and an expectation that students will learn to make and counter arguments based on evidence.

Developing Critical Thinking

Critical thinking skills involve evaluating conclusions by logically and systematically examining the problem, the evidence, and the solution. They are useful in almost every life situation—even in evaluating the media ads that constantly bombard us. When you see a group of gorgeous people extolling the virtues of a particular brand of orange juice as they frolic in skimpy bathing suits, you must decide if sex appeal is a relevant factor in choosing a fruit drink (remember Pavlovian advertising from Chapter 7).

No matter what approach you use to develop critical thinking, it is important to follow up with additional practice. One lesson is not enough. For example, if your class examined a particular historical document to determine if it reflected bias or propaganda, you should follow up by analyzing other written historical documents, contemporary advertisements, or news stories. Unless thinking skills become overlearned and relatively automatic, they are not likely to be transferred to new situations (Mayer & Wittrock, 2006). Instead, students will use these skills only to complete the lesson in social studies, not to evaluate the claims made by friends, politicians, car manufacturers, or diet plans. Table 9.3 describes the characteristics of a critical thinker.

Critical Thinking in Specific Subjects

The characteristics of critical thinkers in Table 9.3 would be useful in any subject. But some critical thinking skills are specific to a particular subject. For example, to teach history, Jeffrey Nokes and his colleagues investigated (1) using traditional texts versus multiple readings, and (2) direct teaching of critical thinking skills versus no direct teaching of critical thinking skills (Nokes, Dole, & Hacker, 2007). The multiple texts included historical

Critical thinking Evaluating conclusions by logically and systematically examining the problem, the evidence, and the solution.

TABLE 9.3 • What Is a Critical Thinker?

Assuming that critical thinking is reasonable reflective thinking focused on deciding what to believe or do, a critical thinker:

1. Is open minded and mindful of alternatives.
2. Tries to be well informed.
3. Judges well the credibility of sources.
4. Identifies conclusions, reasons, and assumptions.
5. Judges well the quality of an argument, including the acceptability of its reasons, assumptions, and evidence.
6. Can well develop and defend a reasonable position.
7. Asks appropriate clarifying questions.
8. Formulates plausible hypotheses; plans experiments well.
9. Defines terms in a way appropriate for the context.
10. Draws conclusions when warranted, but with caution.
11. Integrates all items in this list when deciding what to believe or do.

Source: Adapted from Robert H. Ennis. Retrieved May 26, 2011, from http://faculty.ed.uiuc.edu/rhennis/index.html.

fiction, excerpts from speeches, government documents, photographs, charts and historical data, and short sections from texts. The history critical thinking skills taught were:

- **Sourcing:** Looking at the source of the document before reading and using that information to help interpret and make inferences about the reading. Is the source biased? Can I trust it?
- **Corroboration:** Making connections between the information in different texts and noting similarities and contradictions.
- **Contextualization:** Imaging the time, place, people, and culture that is the context for the event, with all the political and social forces that might be operating.

Students who learned with multiple texts instead of traditional textbooks actually learned more history content. Also, students were able to learn and apply two of the three critical thinking skills, *sourcing* and *corroboration*, when they were *directly taught* how to use the skills. Contextualization proved more difficult, perhaps because the students lacked the background knowledge to fill in contextual information. So critical thinking for specific subjects can be taught along with the subject. But as you can see in the *Point/Counterpoint*, educators don't agree about the best way to foster critical thinking in schools.

Argumentation

The ability to construct and support a position—to argue—is essential in science, politics, persuasive writing, and critical thinking, to name just a few areas. The heart of **argumentation** (the process of debating a claim with someone else) is supporting your position with evidence and understanding, and then refuting your opponent's claims and evidence. Children are not good at argumentation, adolescents are a bit better, and adults are better still, but not perfect. Children don't pay very much attention to the claims and evidence of the other person in the debate. Adolescents understand that their opponent in a debate has a different position, but they tend to spend much more time presenting their own position than they do trying to understand and critique their opponent's claims. It is as if the adolescents believe "winning an argument" means making a better presentation, but they don't appreciate the need to understand and weaken the opponent's claims (Kuhn & Dean, 2004).

Children and adolescents focus more on their own positions because it is too demanding to remember and process both their own and their opponent's claims and evidence at the same time—the *cognitive load* is just too much. In addition, argumentation skills are not natural. They take both time and instruction to learn (Kuhn, Goh, Iordanou, & Shaenfield, 2008; Udell, 2007).

But what has to be learned? In order to make a case while understanding and refuting the opponent's case, you must be aware of what you are saying, what your opponent is saying, and how to refute your opponent's claims. This takes planning, evaluating how the plan is going, reflecting on what the opponent has said, and changing strategies as

Argumentation The process of debating a claim with someone else.

POINT/COUNTERPOINT Should Schools Teach Critical Thinking and Problem Solving?

The question of whether schools should focus on process or content, problem-solving skills or core knowledge, higher-order thinking skills or academic information has been debated for years. Some educators suggest that students must be taught how to think and solve problems, while other educators assert that students cannot learn to "think" in the abstract. They must be thinking about something—some content. Should teachers focus on knowledge or thinking?

POINT

Problem solving and higher-order thinking can and should be taught. An article in the April 28, 1995, issue of the *Chronicle of Higher Education* makes this claim:

> *Critical thinking is at the heart of effective reading, writing, speaking, and listening. It enables us to link together mastery of content with such diverse goals as self-esteem, self-discipline, multicultural education, effective cooperative learning, and problem solving. It enables all instructors and administrators to raise the level of their own teaching and thinking. (p. A-71)*

Closer to home for you, Peter Facione (2011) claims that critical thinking is related to GPA in university and to reading comprehension. How can students learn to think critically? Some educators recommend teaching thinking skills directly with widely used techniques such as the Productive Thinking Program or CoRT (Cognitive Research Trust). Other researchers argue that learning computer programming languages will improve students' minds and teach them how to think logically. Finally, because expert readers automatically apply certain metacognitive strategies, many educators and psychologists recommend directly teaching novice or poor readers how to apply these strategies. Michael Pressley's Good Strategy User model (Pressley & Harris, 2006) and Palincsar and Brown's (1984) reciprocal teaching approach are successful examples of direct teaching of metacognitive skills. Research on these approaches generally shows improvements in achievement and comprehension for students of all ages who participate (Pressley & Harris, 2006; Rosenshine & Meister, 1994).

Jess Yu/Shutterstock.com

COUNTERPOINT

Thinking and problem-solving skills do not transfer. According to E. D. Hirsch (1996), a vocal critic of critical thinking programs:

> *But whether such direct instruction of critical thinking or self-monitoring does in fact improve performance is a subject of debate in the research community. For instance, the research regarding critical thinking is not reassuring. Instruction in critical thinking has been going on in several countries for over a hundred years. Yet researchers found that students from nations as varied as Israel, Germany, Australia, the Philippines, and the United States, including those who have been taught critical thinking continue to fall into logical fallacies. (p. 136)*

The CoRT program has been used in over 5000 classrooms in 10 nations. But Polson and Jeffries (1985) report that "after 10 years of widespread use we have no adequate evidence concerning the effectiveness of the program" (p. 445). In addition, Mayer and Wittrock (1996) note that field studies of problem solving in real situations show that people often fail to apply the mathematical problem-solving approaches they learn in school to actual problems encountered in the grocery store or home.

Even though educators have been more successful in teaching metacognitive skills, critics still caution that there are times when such teaching hinders rather than helps learning. Robert Siegler (1993) suggests that teaching self-monitoring strategies to low-achieving students can interfere with the students' development of adaptive strategies. Forcing students to use the strategies of experts may put too much burden on working memory as the students struggle to use an unfamiliar strategy and miss the meaning or content of the lesson. For example, rather than teach students strategies for figuring out words from context, it may be helpful for students to focus on learning more vocabulary words.

Beware of Either/Or. One clear message from current research on learning is that both subject-specific knowledge and learing strategies are important. Students today need to be critical consumers of all kinds of knowledge, but critical thinking alone is not enough. Students need the knowledge, vocabulary, and concepts to understand what they are reading, seeing, and hearing. The best teachers can teach math content and how to learn math at the same time, or history and how to critically assess history sources.

needed—in other words, *metacognitive knowledge and skills for argumentation*. Deanna Kuhn and her colleagues (2008) designed a process for developing metacognitive argumentation skills. They presented a class of grade 6 students with the following dilemma.

> The Costa family has moved to the edge of town from far away Greece with their 11-year-old son Nick. Nick was a good student and soccer player back home in Greece. Nick's parents have decided that in this new place, they want to keep Nick at home with them, and not have him be at the school with the other children. The family speaks only Greek, and

> they think Nick will do better if he sticks to his family's language and doesn't try to learn English. They say they can teach him everything he needs at home. What should happen? Is it okay for the Costa family to live in the town but keep Nick at home, or should they be required to send their son to the town school like all the other families do? (p. 1313)

Based on their initial position on the dilemma, the 28 students in the class were divided into two groups—"Nick should go to school" or "Nick should be taught at home." These two groups were divided again into same-gender pairs, and all the "Nick should go to school" pairs moved to a room next door to their class. For about 25 minutes, each pair from one side "debated" a pair in the other room using instant messaging (IM). Later in the week the process was repeated, but with different pairs debating. In all, there were seven IM debates, so every "go to school" pair debated every "stay home" pair over several weeks. After four of the seven sessions, the pairs were given a transcript of the dialogue from their last debate, along with worksheets that scaffolded their *reflection* on their own arguments or the arguments of their opponents. The students evaluated their arguments and tried to improve them, with some adults coaching. These reflective sessions were repeated three times.

Next, there was a "showdown" debate—the entire "go to school" team debated the entire "stay home" team via one computer per team and a smart board. For this debate, half of each team prepared as experts on their position and half as experts *on the opponent's arguments*. After winter break and again after spring break, the whole process was repeated with new dilemmas.

You can see that there were three techniques employed in the study, supported by technology, to help students become more metacognitive about argumentation. First, they had to work in pairs to collaborate and agree on each communication with the opposing pair. Second, the researchers provided the pairs with transcripts of parts of their dialogue with the opponents so the partners could reflect on the discussions. Third, the dialogues were conducted via instant messaging, so the pairs had a permanent record of the discussion.

So what happened? The pairs, IM, and reflection strategies were successful for most students in helping them take into account the opponent's position and create strategies for rebutting the opponent's arguments. Working in pairs seemed to be especially helpful. When adolescents and even adults work alone, they often are not successful at creating effective counterarguments and rebuttals (Kuhn & Franklin, 2006).

Teaching for Transfer

STOP & THINK Think back for a moment to a class in one of your high school subjects that you have not studied in university. 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? This question relates to the important topic of learning transfer. Let's begin with a definition of *transfer*.

Whenever something previously learned influences—for good or bad—current learning, or when solving an earlier problem affects how you solve a new problem, **transfer** has occurred. 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 attempts to apply familiar but *inappropriate* strategies to a new situation.

Transfer Influence of previously learned material on new material; the productive (not reproductive) uses of cognitive tools and motivations.

Actually, there are several dimensions of transfer (Barnett & Ceci, 2002). You can transfer learning across subjects (math skills used in science problems), across physical contexts (learned in school, used on the job), across social contexts (learned alone, used with your family or team), across time periods (learned in university, used months or years later), across functions (learned for academics, used for hobbies and recreation), and across modalities (learned from watching the Home and Garden cable channel, used to discuss ideas for a patio with a landscape architect). So transfer can refer to many different examples of applying knowledge and skills beyond where, when, and how you learned them.

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 fundamental goal of education (Pugh & Bergin, 2006; Shaffer, 2010). Early work focused on specific transfer of skills and the general transfer of *mental discipline* gained from studying rigorous subjects such as Greek or mathematics. But in 1924, E. L. Thorndike demonstrated that there was no mental discipline benefit from learning Greek. Learning Greek just helped you learn more Greek. So, thanks to Thorndike, you were not required to take Greek in high school.

More recently, researchers have distinguished between the automatic, direct use of skills such as reading or writing in everyday applications and the thoughtful transfer of knowledge and strategies to arrive at creative solutions to problems (Bereiter, 1995; Bransford & Schwartz, 1999; Salomon & Perkins, 1989). The key to thoughtful transfer is *mindful abstraction*, or the deliberate identification of a principle, main idea, strategy, or procedure that is not tied to one 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) added another key—a resource-rich environment that supports productive, appropriate transfer. Table 9.4 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 at grocery stores (Lave, 1988; Lave & Wenger, 1991). This happens because learning is *situated*—tied to specific situations. 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?

TABLE 9.4 • **Kinds of Transfer**

	DIRECT-APPLICATION	PREPARATION FOR FUTURE LEARNING
Definition	Automatic transfer of highly practiced skill	Conscious application of abstract knowledge to a new situation Productive use of cognitive tools and motivations
Key Conditions	Extensive practice Variety of settings and conditions Overlearning to automaticity	Mindful focus on abstracting a principle, main idea, or procedure that can be used in many situations Learning in powerful teaching-learning environments
Examples	Driving many different cars Finding your gate in an airport	Applying KWL or READS strategies Applying procedures from math in designing a page layout for the school newspaper

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HIGHER-LEVEL TRANSFER Students will be more likely to transfer knowledge to new situations if they have been actively involved in the learning process. They should be encouraged to form abstractions that they will apply later, so the students know transfer is an important goal.

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 basic skills 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 children, none of us studied anything about computers; yet now we spend most of every day using them, and Phil even designs software for researching how students learn. He also learned to use a slide rule. Now, calculators and computers have made this skill obsolete. We were encouraged to take advanced math and physics instead of typing in high school. Those were great classes, but we still struggle with keyboarding—who knew? Undoubtedly, changes as extreme and unpredictable as these await the students you will teach. For this reason, the general transfer of principles, attitudes, learning strategies, self-motivation, time management skills, 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 **overlearning**, practising 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 develop automated basic skills as we saw in Chapter 9.

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. Students should be encouraged to form abstractions that they will apply later, so they know transfer is an important goal. It also helps if students form deep connections between the new knowledge and their existing structures of knowledge as well as connections to their everyday experiences (Pugh & Bergin, 2007). 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, that are similar to those 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. For now, the *Family and Community Partnerships Guidelines* give ideas for enlisting support from families to encourage transfer.

There is one last kind of transfer that is especially important for students—the transfer of the *learning strategies* we encountered earlier. Learning strategies are meant to be applied across a wide range of situations.

Overlearning Practising a skill past the point of mastery.

STAGES OF TRANSFER FOR STRATEGIES. Gary Phye (1992, 2001; Phye & Sanders, 1994) 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 also rehearse the strategy and practise 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*, students should be given new problems that can be solved with the same strategy, even though the problems appear different on the surface. To enhance motivation, teachers should 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 self-regulatory knowledge—*how* to use the strategy as well as *when* and *why*.

For all students, there is a positive relationship between using learning strategies and academic gains such as high school GPA and retention in university (Robbins, Le, & Lauver, 2005). Some students will learn productive strategies on their own, but all students can benefit from direct teaching, modelling, and practice of learning strategies and study skills. This is one important way to prepare all of your students for the future. Newly mastered concepts, principles, and strategies must be applied in a wide variety of situations and with many types of problems (Chen & Mo, 2004). Positive transfer is encouraged when skills are practised under authentic conditions, similar to those that will exist when the skills are needed later. Students can learn to write by corresponding with email pen pals in other countries. They can learn historical research methods by studying their own family history. Some of these applications should involve complex, ill-defined, unstructured problems, because many of the problems to be faced in later life, both in school and out, will not come to students complete with instructions.

GUIDELINES FAMILY AND COMMUNITY PARTNERSHIPS

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 practise, extend, or apply learning from school.

Examples

1. To extend writing, ask parents to encourage their children to write letters or emails 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.

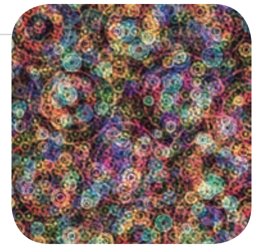
Make families partners in practising learning strategies.

Examples

1. Focus on one learning strategy at a time—ask families to simply remind their children to use a particular strategy with homework that week.
2. Develop a lending library of books and videos to teach families about learning strategies.
3. Give parents a copy of the Becoming an Expert Student Guidelines on page 303, rewritten for your grade level.

For more information on promoting transfer, see http://education.purduecal.edu/Vockell/EdPsyBook.

SUMMARY


liubomir/Shutterstock.com

Metacognition (pp. 293–296)

What are the three metacognitive skills? The three metacognitive skills used to regulate thinking and learning are planning, monitoring, and evaluating. Planning involves deciding how much time to give to a task, which strategies to use, how to start, and so on. Monitoring is the real-time awareness of "how I'm doing." Evaluating involves making judgments about the processes and outcomes of thinking and learning and acting on those judgments.

What are some sources of individual differences in metacognition? Individual differences in metacognition may result from different paces of development (maturation) or biological differences among learners. For example, young students may not be able to understand a lesson's purpose as well as older students.

How can teachers help students develop metacognitive knowledge and skills? With younger students, teachers can help students "look inside" to identify what they do to read, write, or learn better. Systems such as KWL can help if teachers demonstrate, explain, and model the strategy. For older students, teachers can build self-reflective questions into assignments and learning materials.

Learning Strategies (pp. 296–304)

What are learning strategies? Learning strategies are a special kind of procedural knowledge—*knowing how* to do something. A strategy for learning might include 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 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.

Problem Solving (pp. 304–315)

What is problem solving? Problem solving is both general and domain specific. 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. General problem-solving strategies usually include the steps of *identifying* the problem, *setting goals*, *exploring* possible solutions and consequences, *acting*, and finally *evaluating* the outcome. Both general and specific problem solving are valuable and necessary.

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, working backward, analogical thinking, 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 on to 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.

Creativity and Creative Problem Solving (pp. 315–319)

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 five 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.

What can teachers do to support creativity in the classroom? Multicultural experiences appear to help students think flexibly and creatively. Teachers can encourage creativity in their interactions with students by accepting unusual, imaginative answers, modelling divergent thinking, using brainstorming, and tolerating dissent.

Critical Thinking and Argumentation (pp. 319–322)

What is critical thinking? Critical thinking skills include defining and clarifying the problem, making judgments about the consistency and adequacy of the information related to a problem, and drawing conclusions. No matter what approach you use to develop critical thinking, it is important to follow up activities with additional practice. One lesson is not enough—overlearning will help students use critical thinking in their own lives.

What is argumentation? The heart of argumentation (the process of debating a claim with someone else) is supporting your position with evidence and understanding, and then refuting your opponent's claims and evidence. Argumentation skills are not natural. They take both time and instruction to learn. It is especially difficult for children and adolescents to pay attention to, understand, and refute the opponent's position with evidence.

Teaching for Transfer (pp. 322–325)

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.

What are some dimensions of transfer? Information can be transferred across a variety of contexts. Some examples include transfer from one subject to another, one physical location to another, or one function to another. These types of transfer make it possible to use skills developed in one area for many other tasks.

Distinguish between automatic and mindful, intentional transfer. Spontaneous application of well-learned knowledge and skills is automatic transfer. Mindful, intentional transfer involves reflection and deliberate 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.

▼ WHAT WOULD THEY DO?

TEACHERS' CASEBOOK: Uncritical Thinking

Here is how some practising teachers would help students learn to critically evaluate the information they find on the internet.

JOHN BALDASSARRE

Formerly from Archbishop Oscar Romero High School, Edmonton, AB

When assigning a "research" paper, I find it extremely valuable to start the process early in the year by presenting students with a website that features a fake news story that appears to be real. I ask students to begin to discuss and evaluate the story that is presented and to discuss any similar events that are taking place in the world at the time. After a lengthy discussion, I reveal to the students the fact that the website and the news story are fake and begin to show them how to establish the validity of a website or author. I ask students to consider the following basic questions:

- Who is the author of the news story or website, and what is his or her background? Is there anything on the site that could bias the information?
- What is the purpose of the website? Is it affiliated with any other sites (political parties, social action groups, etc.)? Is it associated with a specific domain, or is it a personal site?
- How active and recent is the website?
- Is the content based on opinions or on studies and/or articles? Can those studies or articles be accessed?
- Can you find the same information stated on other websites or within more traditional, print-based research materials?

I then ask students to apply the above criteria to each research paper that I assign. Students come to realize that they need to research more than one source of information and that they must develop the ability to discern information and to filter bias and opinions from the objective facts. In teaching and advocating this type of methodology and critical thinking process, I also try to function as a role model and demonstrate to students how to filter through a plethora of information to find the sources that are best suited to the task.

ALANNA KING

Orangeville District Secondary School, Orangeville, ON

One technique I use to help students critically evaluate research obtained through internet sources is to show four examples of websites and then walk the students through how to rank the sites from worst to best. For this activity, I break the class into small groups and ask students to develop their own criteria and to sort the examples. As a class, we then list all of the criteria together. Rather than give the students the criteria in advance, they are expected to actively engage with these exemplars for comparison and to express their own ideas about the websites. Together, we develop a common class lexicon for discussing the authority and reliability of websites for research. Students now have a clear understanding of the expectations associated with choosing internet research sources. Another advantage of this activity is that the students become dissatisfied with websites that are inadequate after interacting with good ones.

This activity also involves asking the students to engage with a "citation tool" from the beginning of their research, which reinforces the value of finding quality internet sources. Most digital citation tools now produce excellent quality reference pages based on user input. Poor websites have very little information to plug into the citation tool, and sometimes students find that they can't even locate an author or copyright date. Using the citation tool during the research process, rather than at the end of an assignment, helps students to manage their own research process.

Many students don't know how to use research material as evidence for an argument, so finding deeper web-based sources is critical to success. I think students undervalue their own voices and don't know how to recognize and appreciate their own ideas during research. I model how to analyze a paragraph on my digital projector, and think aloud in front of the students, so they can see how I'm developing ideas and connecting them to my research question. Next, I give students a reading from a website and invite them to listen to their own thoughts as they read silently. I suggest that these thoughts might help to

- predict what is next
- connect to their own experiences
- connect to other texts they've experienced
- connect to current events

During this close reading, students recognize once again the importance of choosing quality internet research. Engaging with the text on multiple levels helps students learn how to critically evaluate web sources.