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THEORY AND PRACTICE, 7/E

Robert E. Slavin

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DRAFT

Chapter 8

Chapter Outline

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Student-Centered and Constructivist Approaches to Instruction

"You'll all recall," began Mr. Dunbar, "how last week we figured out how to compute the area of a circle and the volume of a cube. Today you're going to have a chance to discover how to compute the volume of a cylinder. This time, you're really going to be on your own. At each of your lab stations you have five unmarked cylinders of different sizes. You also have a metric ruler and a calculator, and you may use water from your sink. The most important resources you'll have to use, however, are your minds and your partners. Remember, at the end of this activity, everyone in every group must be able to explain not only the formula for volume of a cylinder, but also precisely how you derived it. Any questions? You may begin!"

The students in Mr. Dunbar's middle school math and science class got right to work. They were seated around lab tables in groups of four. One of the groups, the Master Minds, started off by filling all its cylinders with water.

"OK," said Miguel, "we've filled all of our cylinders. What do we do next?"

"Let's measure them," suggested Margarite. She took the ruler and asked Dave to write down her measurements.

"The water in this little one is 36 millimeters high and . . . just a sec . . . 42 millimeters across the bottom."

"So what?" asked Yolanda. "We can't figure out the volume this way. Let's do a little thinking before we start measuring everything."

"Yolanda's right," said Dave. "We'd better work out a plan."

"I know," said Miguel, "let's make a hypo . . . , hypotha . . . , what's it called?"

"Hypothesis," said Yolanda. "Yeah! Let's guess what we think the solution is."

"Remember how Mr. Dunbar reminded us about the area of a circle and the volume of a cube? I'll bet that's an important clue."

"You're right, Miguel," said Mr. Dunbar, who happened to be passing by. "But what are you guys going to do with that information?"

The Master Minds were quiet for a few moments. "Let's try figuring out the area of the bottom of one of these cylinders," ventured Dave. "Remember that Margarite said the bottom of the little one was 42 millimeters? Give me the calculator . . . now how do we get the area?"

Yolanda said, "I think it was pi times the radius squared."

"That sounds right. So 42 squared. . . ."

"Not 42; 21 squared," interrupted Margarite. "If the diameter is 42, the radius is 21."

"OK, OK, I would have remembered. Now, 21 squared is . . . 441, and pi is about 3.14, so my handy-dandy calculator says . . . 13,847."

"Can't be," said Miguel. "Four hundred times three is twelve hundred, so 441 times 3.14 can't be thirteen thousand. I think you did something wrong."

"Let me do it again . . . 441 times 3.14 . . . you're right. Now it's about 1,385."

"So what?" said Yolanda.

"That doesn't tell us how to figure the volume!"

Margarite jumped in excitedly. "Just hang on for a minute, Yolanda. Now, I think we should multiply the area of the bottom by the height of the water."

"But why?" asked Miguel.

"Well," said Margarite, "when we did the volume of a cube, we multiplied length times width times height. Length times width is the area of the bottom. I'll bet we could do the same with a cylinder!"

"The girl's brilliant!" said Miguel. "Sounds good to me. But how could we prove it?"

"I've got an idea," said Yolanda. She emptied the water out of all the cylinders and filled the smallest one to the top. "This is my idea. We don't know what the volume of this cylinder is, but we do know that it's always the same. If we pour the same amounts of water into all four cylinders and use our formula, it should always come out to the same amount!"

"Let's try it!" said Miguel. He poured the water from the small cylinder into a larger one, refilled it, and poured it into another of a different shape.

The Master Minds measured the bases and the heights of the water in their cylinders, wrote down the measurements, and tried out their formula. Sure enough, their formula always gave the same answer for the same volume of water. In great excitement they called Mr. Dunbar to come see what they were doing. Mr. Dunbar asked each of the students to explain what they had done.

"Terrific!" he said. "Not only did you figure out a solution, but everyone in the group participated and understood what you did. Now I'd like you to help me out. I've got a couple of groups that are really stumped. Do you suppose you could help them? Don't give them the answer, but help them get on track. How about Yolanda and Miguel helping with the Brainiacs, and Dave and Margarite help with the Dream Team. OK? Thanks!" ■

USING YOUR *Experience*

Cooperative Learning and Critical Thinking After reading this case, randomly select or appoint a four- to eight-member panel of "experts" on constructivism who sit in front of the class to explain why this method of teaching worked so well for Mr. Dunbar in his middle school math and science classroom. (Students might want to volunteer for the panel.) Members of the audience can ask questions once each panelist has spoken.

Critical Thinking Reflect on Mr. Dunbar's teaching style. How would you characterize it (e.g., Piagetian, Vygotskian, discovery, other)? How does he frame the task and interact with students? His addressing of students' prior learning and questioning are critical from a constructivist point of view. Why?

Learning is much more than memory. For students to really understand and be able to apply knowledge, they must work to solve problems, to discover things for themselves, to wrestle with ideas. Mr. Dunbar could have told his students that the formula for the volume of a cylinder is $\Pi r^2 h$. With practice the students would have been able to feed numbers into this formula and grind out correct answers. But how much would it have meant to them, and how well could they have applied the ideas behind the formula to other problems? The task of education is not to pour information into students' heads, but to engage students' minds with powerful and useful concepts. The focus of this chapter is to examine ways of doing this.

What Is the Constructivist View of Learning?

One of the most important principles of educational psychology is that teachers cannot simply give students knowledge. Students must construct knowledge in their own minds. The teacher can facilitate this process by teaching in ways that make information meaningful and relevant to students, by giving students opportunities to discover or apply ideas themselves, and by teaching students to be aware of and consciously use their own strategies for learning. Teachers can give students ladders that lead to higher understanding, yet the students themselves must climb these ladders.

A revolution is taking place in educational psychology. This revolution goes by many names, but the name that is most frequently used is **constructivist theories of learning**. The essence of constructivist theory is the idea that learners must individually discover and transform complex information if they are to make it their own (Anderson, Greeno, Reder, & Simon, 2000; Brown, Collins, & Duguid, 1989;

constructivist theories of learning
Theories that state that learners must individually discover and transform complex information, checking new information against old rules and revising rules when they no longer work.

Steffe & Gale, 1995; Tishman, Perkins, & Jay, 1995; Waxman, Padron, & Arnold, 2001). Constructivist theory sees learners as constantly checking new information against old rules and then revising rules when they no longer work. This view has profound implications for teaching, as it suggests a far more active role for students in their own learning than is typical in many classrooms. Because of the emphasis on students as active learners, constructivist strategies are often called *student-centered instruction.* In a student-centered classroom the teacher becomes the "guide on the side" instead of the "sage on the stage," helping students to discover their own meaning instead of lecturing and controlling all classroom activities (Weinberger & McCombs, 2001; Windschitl, 1999).

CONNECTIONS
The work of Piaget and of Vygotsky is discussed on pages 000–000 of Chapter 2.

Historical Roots of Constructivism

The constructivist revolution has deep roots in the history of education. It draws heavily on the work of Piaget and Vygotsky (recall Chapter 2), both of whom emphasized that cognitive change takes place only when previous conceptions go through a process of disequilibration in light of new information. Piaget and Vygotsky also emphasized the social nature of learning, and both suggested the use of mixed-ability learning groups to promote conceptual change.

SOCIAL LEARNING Modern constructivist thought draws most heavily on Vygotsky's theories (see John-Steiner & Mahn, 1996; Karpov & Bransford, 1995), which have been used to support classroom instructional methods that emphasize cooperative learning, project-based learning, and discovery. Four key principles derived from Vygotsky's ideas have played an important role. First is his emphasis on the social nature of learning (Hickey, 1997; O'Connor, 1998; Salomon & Perkins, 1998). Children learn, he proposed, through joint interactions with adults and more capable peers. On cooperative projects, like the one in Mr. Dunbar's class, children are exposed to their peers' thinking processes; this method not only makes the learning outcome available to all students, but also makes other students' thinking processes available to all. Vygotsky noted that successful problem solvers talk themselves through difficult problems. In cooperative groups, children can hear this inner speech out loud and can learn how successful problem solvers are thinking through their approaches.

CONNECTIONS
For more on the zone of proximal development, see Chapter 2, page 000.

ZONE OF PROXIMAL DEVELOPMENT A second key concept is the idea that children learn best the concepts that are in their zone of proximal development. As discussed in Chapter 2, children are working within their zone of proximal development when they are engaged in tasks that they could not do alone but can do with the assistance of peers or adults. For example, if a child could not find the median of a set of numbers by himself but could do so with some assistance from his teacher, then finding medians is probably in his zone of proximal development. When children are working together, each child is likely to have a peer performing on a given task at a slightly higher cognitive level, exactly within the child's zone of proximal development.

cognitive apprenticeship
The process by which a learner gradually acquires expertise through interaction with an expert, either an adult or an older or more advanced peer.

COGNITIVE APPRENTICESHIP Another concept derived from Vygotsky's emphases both on the social nature of learning and on the zone of proximal development is **cognitive apprenticeship** (Greeno, Collins, & Resnick, 1996; Harpaz & Lefstein, 2000). This term refers to the process by which a learner gradually acquires expertise through interaction with an expert, either an adult or an older or more advanced peer. In many occupations, new workers learn their jobs through a process of apprenticeship, in which a new worker works closely with an expert, who provides a model, gives feedback to the less experienced worker, and gradually socializes the new worker into the norms and behaviors of the profession. Student teaching is a form of apprenticeship. Constructivist theorists suggest that teachers transfer this long-standing and highly effective model of teaching and learning to day-to-day activities in classrooms, both by engaging students in complex tasks and helping them through these tasks (as a master electrician would help an apprentice rewire a house) (Hamman, Berthelot, Saia, & Crowley, 2000; Newmann & Wehlage, 1993) and by engaging students in heterogeneous, cooperative learning groups in which more advanced students help less advanced ones through complex tasks.

MEDIATED LEARNING Finally, Vygotsky's emphasis on scaffolding, or mediated learning (Kozulin & Presseisen, 1995), is important in modern constructivist thought. Current interpretations of Vygotsky's ideas emphasize the idea that students should be given complex, difficult, realistic tasks and then be given enough help to achieve these tasks (rather than being taught little bits of knowledge that are expected someday to build up to complex tasks). This principle is used to support the classroom use of projects, simulations, explorations in the community, writing for real audiences, and other authentic tasks (Byerly, 2001; Holt & Willard-Holt, 2000). The term situated learning (Anderson, Greeno, Reder, & Simon, 2000; Prawat, 1992) is used to describe learning that takes place in real-life, authentic tasks.

Top-Down Processing

Constructivist approaches to teaching emphasize top-down rather than bottom-up instruction. The term *top-down* means that students begin with complex problems to solve and then work out or discover (with the teacher's guidance) the basic skills required. For example, students might be asked to write compositions and only later learn about spelling, grammar, and punctuation. This top-down processing approach is contrasted with the traditional bottom-up strategy, in which basic skills are gradually built into more complex skills. In top-down teaching, the tasks students begin with are complex, complete, and authentic, meaning that they are not parts or simplifications of the tasks that students are ultimately expected to perform but are the actual tasks. As one instance of a constructivist approach to mathematics teaching, consider an example from Lampert (1986). The traditional, bottom-up approach to teaching the multiplication of two-digit numbers by one-digit numbers (e.g., $4 \times 12 = 48$) is to teach students a step-by-step procedure to get the right answer. Only after students have mastered this basic skill are they given simple application problems, such as "Sondra saw some pencils that cost 12 cents each. How much money would she need to buy four of them?"

The constructivist approach works in exactly the opposite order, beginning with problems (often proposed by the students themselves) and then helping students figure out how to do the operations. Lampert's example of this appears in Figure 8.1.

For example, in the chapter-opening vignette, Mr. Dunbar used cooperative groups to help students derive a formula for the volume of a cylinder. Recall how the Master Minds bounced ideas off of each other, tried out and discarded false leads, and ultimately came up with a solution and a way to prove that their solution was correct. None of the students could have solved the problem alone, so the group work was helpful in arriving at a solution. More important, the experience

Teacher: Can anyone give me a story that could go with this multiplication . . . 12×4?

Student 1: There were 12 jars, and each had 4 butterflies in it.

Teacher: And if I did this multiplication and found the answer, what would I know about those jars and butterflies?

Student 1: You'd know you had that many butterflies altogether.

Teacher: Okay, here are the jars. [*Draws a picture to represent the jars of butterflies—see diagram.*] Now, it will be easier for us to count how many butterflies there are altogether if we think of the jars in groups. And, as usual, the mathematician's favorite number for thinking about groups is?

Student 2: 10

Teacher: Each of these 10 jars has 4 butterflies in it. [*Draws a loop around 10 jars.*]

Teacher: Suppose I erase my circle and go back to looking at the 12 jars again all together: Is there any other way I could group them to make it easier for us to count all the butterflies?

Student 3: You could do 6 and 6.

Teacher: Now, how many do I have in this group?

Student 4: 24

Teacher: How did you figure that out?

Student 4: 8 and 8 and 8. [*He puts the 6 jars together into 3 pairs, intuitively finding a grouping that made the figuring easier for him.*]

Teacher: That's 3×8. It's also 6×4. Now how many are in this group?

Student 3: 24. It's the same. They both have 6 jars.

Teacher: And how many are there altogether?

Student 5: 24 and 24 is 48.

Teacher: Do we get the same number of butterflies as before? Why?

Student 5: Yeah, because we have the same number of jars and they still have 4 butterflies in each.

FIGURE 8.1 ■ **Mathematical Stories for Teaching Multiplication**

From Magdalene Lampert, "Knowing, Doing and Teaching Multiplication," *Cognition and Instruction, 3,* 1986, pp. 305–342. Reprinted by permission of Lawrence Erlbaum Associates, Inc.

of hearing others' ideas, trying out and receiving immediate feedback on proposed solutions, and arguing about different ways to proceed gave the Master Minds the cognitive scaffolding that Vygotsky, Bruner, and other constructivists hold to be essential to higher-order learning (Brooks & Brooks, 1993).

Cooperative Learning

Constructivist approaches to teaching typically make extensive use of cooperative learning, on the theory that students will more easily discover and comprehend difficult concepts if they can talk with each other about the problems. Again, the emphasis on the social nature of learning and the use of groups of peers to model appropriate ways of thinking and expose and challenge each other's misconceptions are key elements of Piaget's and Vygotsky's conceptions of cognitive change (Pontecorvo, 1993). Cooperative learning methods are described in more detail later in this chapter.

Discovery Learning

Discovery learning is an important component of modern constructivist approaches that has a long history in education innovation. In **discovery learning** (Bergstrom & O'Brien, 2001; Wilcox, 1993), students are encouraged to learn largely on their own through active involvement with concepts and principles, and teachers encourage students to have experiences and conduct experiments that permit them to discover principles for themselves. Bruner (1966), an advocate of discovery learning, put it this way: "We teach a subject not to produce little living libraries on that subject, but rather to get a student to think . . . for himself, to consider matters as an historian does, to take part in the process of knowledge-getting. Knowing is a process, not a product" (1966, p. 72).

discovery learning
A constructivist approach to teaching in which students are encouraged to discover principles for themselves.

These students are encouraged to learn on their own. What are some of the advantages of discovery learning?

Discovery learning has applications in many subjects. For example, some science museums have a series of cylinders of different sizes and weights, some hollow and some solid. Students are encouraged to race the cylinders down a ramp. By careful experimentation the students can discover the underlying principles that determine the cylinders' speed. Computer simulations can create environments in which students can discover scientific principles (DeJong & van Joolingen, 1998). After-school enrichment programs (Bergstrom & O'Brien, 2001) and innovative science programs (Singer et al., 2000) are particularly likely to be based on principles of discovery learning.

Discovery learning has several advantages. It arouses students' curiosity, motivating them to continue to work until they find answers. Students also learn independent problem-solving and critical-thinking skills, because they must analyze and manipulate information.

CONNECTIONS

For more on the motivational aspects of self-regulated learning, see Chapter 10, page 000.

Self-Regulated Learning

A key concept of constructivist theories of learning is a vision of the ideal student as a self-regulated learner (Paris & Paris, 2001; Weinstein & McCombs, 1995). **Self-regulated learners** are ones who have knowledge of effective learning strategies and how and when to use them (Bandura, 1991; Dembo & Eaton, 2000; Schunk & Zimmerman, 1997; Winne, 1997). For example, they know how to break complex problems into simpler steps or to test out alternative solutions (Greeno & Goldman, 1998); they know how and when to skim and how and when to read for deep understanding; and they know how to write to persuade and how to write to inform (Zimmerman & Kitsantas, 1999). Further, self-regulated learners are motivated by learning itself, not only by grades or others' approval (Boekaerts, 1995; Corno, 1992; Schunk, 1995), and they are able to stick to a long-term task until it is done. When students have both effective learning strategies and the motivation and persistence to apply these strategies until a job is done to their satisfaction, then they are likely to be effective learners (Williams, 1995; Zimmerman, 1995) and to have a lifelong motivation to learn (Corno & Kanfer, 1993).

CONNECTIONS

For more on scaffolding, see Chapter 2, page 000.

Scaffolding

As was noted in Chapter 2, scaffolding is a practice based on Vygotsky's concept of assisted learning. According to Vygotsky, higher mental functions, including the ability to direct memory and attention in a purposeful way and to think in symbols, are mediated behaviors. Mediated externally by culture, these and other behaviors become internalized in the learner's mind as psychological tools. In assisted learning, or **mediated learning,** the teacher is the cultural agent who guides instruction so that students will master and internalize the skills that permit higher cognitive functioning. The ability to internalize cultural tools relates to the learner's age or stage of cognitive development. Once acquired, however, internal mediators allow greater self-mediated learning.

In practical terms, scaffolding might include giving students more structure at the beginning of a set of lessons and gradually turning responsibility over to them to operate on their own (Palincsar, 1986; Rosenshine & Meister, 1992, 1994). For example, students can be taught to generate their own questions about material they are reading. Early on, the teacher might suggest the questions, modeling the kinds of questions students might ask, but students later take over the question-generating task. For another example of scaffolding, see Figure 8.2.

self-regulated learners
Students who have knowledge of effective learning strategies and how and when to use them.

mediated learning
Assisted learning; an approach in which the teacher guides instruction by means of scaffolding to help students master and internalize the skills that permit higher cognitive functioning.

Early in the scaffolding process, the teacher may provide more structure and then gradually turn responsibility over to the student. As a teacher, how would you use scaffolding to be most effective?

Here is a brief example of an adult scaffolding a young child's efforts to put a difficult puzzle together.

Jason: I can't get this one in. *(Tries to insert a piece in the wrong place)*

Adult: Which piece might go down here? *(Points to the bottom of the puzzle)*

Jason: His shoes. *(Looks for a piece resembling the clown's shoes but tries the wrong one)*

Adult: Well, what piece looks like this shape? *(Points again to the bottom of the puzzle)*

Jason: The brown one. *(Tries it and it fits; then attempts another piece and looks at the adult)*

Adult: There you have it! Now try turning that piece just a little. *(Gestures to show him)*

Jason: There! *(Puts in several more, commenting to himself, "Now a green piece to match," "Turn it [meaning the puzzle piece]," as the adult watches)*

FIGURE 8.2 ■ Scaffolding

From Laura E. Berk, *Infants, Children, and Adolescents* (2nd ed.), p. 328. Copyright © 1996 by Allyn & Bacon. Reprinted by permission.

Research has measured parents' use of scaffolding while helping fifth-graders with math homework. Researchers measured the degree to which adults shifted their level of intervention to fit the child's zone of proximal development. When the child is having difficulty, the adult who stays within this region increases his or her directiveness just enough to provide support but not so much as to take over the task, then reduces directiveness when the child begins to succeed. Findings revealed that make use of this principle predicted gains in children's learning of mathematics. A later section in this chapter describes reciprocal teaching, a method that uses scaffolding in just this way. Scaffolding is closely related to cognitive apprenticeship; experts working with apprentices typically engage them in complex tasks and then give them decreasing amounts of advice and guidance over time.

APA's Learner-Centered Psychological Principles

In 1992 the American Psychological Association's Task Force on Psychology in Education published a document called *Learner-Centered Psychological Principles: Guidelines for School Redesign and Reform* (American Psychological Association, 1992, 1997; see also Alexander & Murphy, 1994). Revised in 1997, this publication presents a consensus view of principles of learning and motivation among prominent educational psychologists primarily working within the constructivist tradition. Table 8.1 shows the APA's 14 principles.

The Learner-Centered Psychological Principles paint a picture of the learner as actively seeking knowledge by (1) reinterpreting information and experience for himself or herself, (2) being self-motivated by the quest for knowledge (rather than being motivated by grades or other rewards), (3) working with others to socially construct meaning, and (4) being aware of his or her own learning strategies and capable of applying them to new problems or circumstances.

Constructivist Methods in the Content Areas

Constructivist and student-centered methods have come to dominate current thinking in all areas of curriculum (see Gagnon & Collay, 2001; Mayer, 2001; Windschitl, 1999). The following sections describe constructivist approaches in reading, mathematics, and science.

RECIPROCAL TEACHING IN READING One well-researched example of a constructivist approach based on principles of question generation is **reciprocal teaching** (Palincsar & Brown, 1984). This approach, designed primarily to help low achievers in elementary and middle schools learn reading comprehension, involves the teacher working with small groups of students. Initially, the teacher models questions students might ask as they read, but students are soon appointed to act as "teacher" to generate questions for each other. Figure 8.3 on page 266 presents an example of reciprocal teaching in use. Note in the example how the teacher directs the conversation about crows at first but then turns the responsibility over to Jim (who is about to turn it over to another student as the example ends). The teacher is modeling the behaviors she wants the students to be able to do on their own and then changes her role to that of facilitator and organizer as the students begin to generate the actual questions. Research on reciprocal teaching has generally found this strategy to increase the achievement of low achievers (Alfassi, 1998; Carter, 1997; Lysynchuk, Pressley, & Vye, 1990; Palincsar & Brown, 1984; Rosenshine & Meister, 1994).

reciprocal teaching
A small-group teaching method based on principles of question generation; through instruction and modeling, teachers foster metacognitive skills primarily to improve the reading performance of students who have poor comprehension.

TABLE 8.1

Learner-Centered Psychological Principles: Cognitive and Metacognitive Factors

PRINCIPLE	EXPLANATION
Principle 1 Nature of the learning process	The learning of complex subject matter is most effective when it is an intentional process of constructing meaning from information and experience.
Principle 2 Goals of the learning process	The successful learner, over time and with support and instructional guidance, can create meaningful, coherent representations of knowledge.
Principle 3 Construction of knowledge	The successful learner can link new information with existing knowledge in meaningful ways.
Principle 4 Strategic thinking	The successful learner can create and use a repertoire of thinking and reasoning strategies to achieve complex learning goals.
Principle 5 Thinking about thinking	Higher-order strategies for selecting and monitoring mental operations facilitate creative and critical thinking.
Principle 6 Context of learning	Learning is influenced by environmental factors, including culture, technology, and instructional practices.
Principle 7 Motivational and emotional influences on learning	What and how much is learned is influenced by the learner's motivation. Motivation to learn, in turn, is influenced by the individual's emotional states, beliefs, interests and goals, and habits of thinking.
Principle 8 Intrinsic motivation to learn	The learner's creativity, higher-order thinking, and natural curiosity all contribute to motivation to learn. Intrinsic motivation is stimulated by tasks that are of optimal novelty and difficulty, are relevant to personal interests, and provide for personal choice and control.
Principle 9 Effects of motivation on effort	Acquisition of complex knowledge and skills requires extended learner effort and guided practice. Without learners' motivation to learn, the willingness to exert this effort is unlikely without coercion.
Principle 10 Developmental influences on learning	As individuals develop, they encounter different opportunities and enperience different constraints for learning. Learning is most effective when differential development within and across physical, intellectual, emotional, and social domains is taken into account.
Principle 11 Social influences on learning	Learning is influenced by social interactions, interpersonal relations, and communication with others.
Principle 12 Individual differences in learning	Learners have different strategies, approaches, and capabilities for learning that are a function of prior experience and heredity.
Principle 13 Learning and diversity	Learning is most effective when differences in learners' linguistic, cultural, and social backgrounds are taken into account.
Principle 14 Standards and assessment	Setting appropriately high and challenging standards and assessing the learner and learning progress—including diagnostic, process, and outcome assessment—are integral parts of the learning process.

Source: From American Psychological Association, *Learner-centered psychological principles: A framework for school redesign and reform,* pp. 4–7. Copyright © 1997 by the American Psychological Association. Adapted by permission.

Teacher: The title of this story is "Genius with Feathers." Let's have some predictions. I will begin by guessing that this story will be about birds that are very smart. Why do I say that?

First student: Because a genius is someone very smart.

Second student: Because they have feathers.

Teacher: That's right. Birds are the only animals that have feathers. Let's predict now the kind of information you might read about very smart birds.

Third student: What kinds of birds?

Teacher: Good question.What kinds would you guess are very smart?

Third student: Parrots or blue jays.

First student: A cockatoo.

Teacher: What other information would you want to know? *[No response from students]*

Teacher: I would like to know what these birds do that is so smart. Any ideas?

Second student: Some birds talk.

Fourth student: They can fly.

Teacher: That's an interesting one. As smart as people are, they can't fly. Well, let's read this first section now and see how many of our predictions were right. I will be the teacher for this section. [*All read the section silently.*]

Teacher: Who is the genius with feathers?

First student: Crows.

Teacher: That's right. We were correct in our prediction that this story would be about birds, but we didn't correctly guess which kind of bird, did we? My summary of the first section would be that it describes the clever things that crows do, which make them seem quite intelligent.

Let's read on. Who will be the teacher for this section? Jim?

Jim: How do crows communicate with one another?

Teacher: Good question! You picked right up on our prediction that this is about the way crows communicate. Whom do you choose to answer your question?

Jim: Barbara.

Barbara: Crows have built-in radar and a relay system.

Jim: That's a good part of it. That answer I wanted was how they relay the messages from one crow to the other crow.

Teacher: Summarize now.

Jim: This is about how crows have developed a system of communication.

Teacher: That's right. The paragraph goes on to give examples of how they use pitch and changes in interval, but these are supporting details. The main idea is that crows communicate through a relay system, Jim?

Jim: It says in this section that crows can use their communication system to play tricks, so I predict the next section will say something about the tricks crows play. I would like Sue to be the next teacher.

Teacher: Excellent prediction. The last sentence of a paragraph often suggests what the next paragraph will be about. Good, Jim.

FIGURE 8.3 Example of a Reciprocal Teaching Lesson

From Anne Marie Palinscar, "The Role of Dialogue in Providing Scaffolded Instruction," *Educational Psychologist, 21,* 1986, pp. 73–98. Adapted by permission of Lawrence Erlbaum Associates, Inc.

THEORY *into* Practice

Introducing Reciprocal Teaching

In introducing reciprocal teaching to students, you might begin as follows: "For the coming weeks we will be working together to improve your ability to understand what you read. Sometimes we are so busy figuring out what the words are that we fail to pay much attention to what the words and sentences mean.

We will be learning a way to pay more attention to what we are reading. I will teach you to do the following activities as you read:

1. To think of important questions that might be asked about what is being read and to be sure that you can answer those questions.
2. To summarize the most important information that you have read.
3. To predict what the author might discuss next in the passage.
4. To point out when something is unclear in the passage or doesn't make sense and then to see if we can make sense of it.

"These activities will help you keep your attention on what you are reading and make sure that you are understanding it.

"The way in which you will learn these four activities is by taking turns in the role of teacher during our reading group sessions. When I am the teacher, I will show you how I read carefully by telling you the questions I made up while reading, by summarizing the most important information I read, and by predicting what I think the author might discuss next. I will also tell you if I found anything I read to be unclear or confusing and how I made sense out of it.

"When you are the teacher, you will first ask the rest of us the questions you made up while reading. You will tell us if our answers are correct. You will summarize the most important information you learned while reading. You will also tell us if you found anything in the passage to be confusing. Several times throughout the story you will also be asked to predict what you think might be discussed next in the passage. When you are the teacher, the rest of us will answer your questions and comment on your summary.

"These are activities that we hope you will learn and use, not only when you are here in reading class, but whenever you want to understand and remember what you are reading—for example, in social studies, science, or history."

Daily Procedures

1. Pass out the passage for the day.
2. Explain that you will be the teacher for the first segment.
3. Instruct the students to read silently whatever portion of the passage you determine is appropriate. At the beginning, it will probably be easiest to work paragraph by paragraph.
4. When everyone has completed the first segment, model the following:
    - "The question that I thought a teacher might ask is . . . "
    - Have the students answer your question. They may refer to the text if necessary. "I would summarize the important information in this paragraph in the following way . . . "
    - "From the title of the passage, I would predict that the author will discuss . . . "
    - If appropriate, "When I read this part, I found the following to be unclear . . . "
5. Invite the students to make comments regarding your teaching and the passage. For example:
    - "Was there more important information?"
    - "Does anyone have more to add to my prediction?"
    - "Did anyone find something else confusing?"

6. Assign the next segment to be read silently. Choose a student to act as teacher for this segment. Begin with students who are more verbal and who you think will have less difficulty with the activities.
7. Coach the student teacher through the activities as necessary. Encourage the other students to participate in the dialogue, but always give the student teacher for that segment the opportunity to go first and lead the dialogue. Be sure to give the student teacher plenty of feedback and praise for his or her participation.
8. As the training days go by, try to remove yourself more and more from the dialogue so that the student teacher initiates the activities herself or himself with students providing feedback. Your role will continue to be monitoring, keeping students on track, and helping them over obstacles. Throughout the training, however, continue to take your turn as teacher, modeling at least once a session.

QUESTIONING THE AUTHOR Another constructivist approach for reading is Questioning the Author (Beck & McKeown, 2001). In this method, children in grades 3–9 are taught to see the authors of factual material as real, fallible people and to then engage in simulated "dialogues" with the authors. As the students are reading a text, the teacher stops them from time to time to ask questions such as "What is the author trying to say, or what does she want us to know?" and then follows up with questions such as "How does that fit in with what she said before?" Ultimately, the students themselves take responsibility for formulating questions of the author's intent and meaning. A study of fifth- and sixth-graders found that students who experienced this technique recalled more from texts than did a comparison group, and were far more likely to describe the purpose of reading as *understanding* rather than just memorizing the text (McKeown & Beck, 1998).

CONSTRUCTIVIST APPROACHES TO MATHEMATICS TEACHING IN THE PRIMARY GRADES Carpenter and colleagues (1994) described four approaches to early mathematics instruction for the early elementary grades. In all four, students work together in small groups; teachers pose problems and then circulate among groups to facilitate the discussion of strategies, join students in asking questions about strategies they have proposed, and occasionally offer alternative strategies when students appear to be stuck. In Supporting Ten-Structured Thinking (STST) (Fuson, 1992), children use base-10 blocks to invent procedures for adding and subtracting large numbers. Conceptually Based Instruction (CBI) (Hiebert & Wearne, 1993) makes extensive use of physical, pictorial, verbal, and symbolic presentations of mathematical ideas and gives students opportunities to solve complex problems using these representations and to contrast different representations of the same concepts. Similarly, the Problem Centered Mathematics Project (PCMP) (Murray, Olivier, & Human, 1992) leads children through stages, from modeling with counters to solving more abstract problems without counters. Cognitively Guided Instruction (CGI) (Carpenter & Fennema, 1992; Fennema, Franke, Carpenter, & Carey, 1993), unlike STST and CBI, does not have a specific curriculum or recommended set of activities but provides extensive professional development for teachers of primary mathematics, focusing on principles similar to those used in the other programs. There is good evidence that this program increases student achievement not only on measures related to higher-level thinking in mathematics, which is the program's focus, but also on computational skills (Carpenter & Fennema, 1992; Carpenter, Fennema, Peterson, Chiang, & Loef, 1989).

In these and other constructivist approaches to mathematics, the emphasis is on beginning with real problems for students to solve intuitively and letting students use their existing knowledge of the world to solve problems any way they can (Greeno & Goldman, 1998; Hiebert et al., 1996; Schifter, 1996). The problem and solutions in Figure 8.1 illustrate this approach. Only at the end of the process, when students have achieved a firm conceptual understanding, are they taught formal, abstract representations of the mathematical processes they have been working with (see Clements & Battista, 1990).

CONSTRUCTIVIST APPROACHES IN SCIENCE Discovery, group work, and conceptual change have long been emphasized in science education, so it is not surprising that many elementary and secondary science educators have embraced constructivist ideas (see Greeno & Goldman, 1998). In this subject, constructivism translates into an emphasis on hands-on, investigative laboratory activities (Bainer & Wright, 1998; Singer, Marx, Krajcik, & Chambers, 2000; White & Frederiksen, 1998); identifying misconceptions and using experimental approaches to correct these misconceptions (Hand & Treagust, 1991; Sandoval, 1995); and cooperative learning (Pea, 1993; Wheatley, 1991).

Research on Constructivist Methods

Research comparing constructivist and traditional approaches to instruction is often difficult to interpret, because constructivist methods are themselves very diverse and are usually intended to produce outcomes that are qualitatively different from those of traditional methods. For example, many researchers argue that acquisition of skills and basic information must be balanced against constructivist approaches (Airasian & Walsh, 1997; Harris & Graham, 1996). But what is the appropriate balance, and for which objectives (Harris & Alexander, 1998; von Glaserfeld, 1996; Waxman, Padrón, & Arnold, 2001)? Also, much of the research on constructivist methods is descriptive rather than comparative. However, there are studies showing positive effects of constructivist approaches on traditional achievement measures in mathematics (e.g., Carpenter & Fennema, 1992), science (e.g., Neale, Smith, & Johnson, 1990), reading (e.g., Duffy & Roehler, 1986), and writing (e.g., Bereiter & Scardamalia, 1987). Furthermore, a study by Knapp (1995) found a correlation between use of more constructivist approaches and achievement gains in high-poverty schools. Weinberger & McCombs (2001) found that students who reported more learner-centered methods used in their classrooms performed at a higher level than other students. Still, much more research is needed to establish the conditions under which constructivist approaches are effective for enhancing student achievement.

SELF-CHECK

INTASC

INTASC Standard 4: Instructional Strategies. A teacher must understand and use a variety of instructional strategies to encourage student development of critical thinking, problem solving, and performance skills.

Write a short essay explaining how each of the following terms is related to constructivist theory: (1) cooperative learning; (2) discovery learning; (3) self-regulated learning.

How Is Cooperative Learning Used in Instruction?

In **cooperative learning** instructional methods, students work together in small groups to help each other learn. Many quite different approaches to cooperative learning exist. Most involve students in four-member, mixed-ability groups (e.g., Slavin, 1994a), but some methods use dyads (e.g., Fantuzzo, Polite, & Grayson, 1990; Maheady, Harper, & Mallette, 1991; O'Donnell & Dansereau, 1992), and some use varying group sizes (e.g., Cohen, 1994b; Johnson & Johnson, 1999; Kagan, 1992; Sharan & Sharan, 1992). Typically, students are assigned to cooperative groups and stay together as a group for many weeks or months. They are usually taught specific skills that will help them work well together, such as active listening, giving good explanations, avoiding putdowns, and including other people.

Cooperative learning activities can play many roles in lessons (Webb & Palincsar, 1996). Recall the chapter-opening vignette in Chapter 7: Ms. Logan used cooperative learning for three distinct purposes. At first, students worked as discovery groups, helping each other figure out how water in bottles could tell them about principles of sound. After the formal lesson, students worked as discussion groups. Finally, students had an opportunity to work together to make sure that all group members had learned everything in the lesson in preparation for a quiz, working in a group study format. In the vignette at the beginning of this chapter, Mr. Dunbar used cooperative groups to solve a complex problem.

CONNECTIONS

To learn about the benefits of cooperative learning methods in promoting harmony in culturally diverse classrooms, see Chapter 4, page 000.

Cooperative Learning Methods

Many quite different cooperative learning methods have been developed and researched. The most extensively evaluated cooperative learning methods are described in the following sections.

STUDENT TEAMS–ACHIEVEMENT DIVISIONS (STAD) In **Student Teams–Achievement Divisions** (STAD) (Slavin, 1994a), students are assigned to four-member learning teams that are mixed in performance level, gender, and ethnicity. The teacher presents a lesson, and then students work within their teams to make sure that all team members have mastered the lesson. Finally, all students take individual quizzes on the material, at which time they may not help one another.

cooperative learning
Instructional approaches in which students work in small mixed-ability groups.

Student Teams–Achievement Divisions (STAD)
A cooperative learning method for mixed-ability groupings involving team recognition and group responsibility for individual learning.

Students' quiz scores are compared to their own past averages, and points are awarded on the basis of the degree to which students meet or exceed their own earlier performance. These points are then summed to form team scores, and teams that meet certain criteria may earn certificates or other rewards. In a related method called Teams–Games–Tournaments (TGT), students play games with members of other teams to add points to their team scores.

STAD and TGT have been used in a wide variety of subjects, from mathematics to language arts to social studies, and have been used from second grade through college. The STAD method is most appropriate for teaching well-defined objectives with single right answers, such as mathematical computations and applications, language usage and mechanics, geography and map skills, and science facts and concepts. However, it can easily be adapted for use with less well-defined objectives by incorporating more open-ended assessments, such as essays or performances. STAD is described in more detail in the next Theory into Practice.

THEORY *into* Practice

Student Teams–Achievement Divisions (STAD)

An effective cooperative learning method is called Student Teams–Achievement Divisions, or STAD (Slavin, 1994a, 1995a). STAD consists of a regular cycle of teaching, cooperative study in mixed-ability teams, and quizzes, with recognition or other rewards provided to teams whose members excel.

STAD consists of a regular cycle of instructional activities, as follows:

- **Teach:** Present the lesson.
- **Team study:** Students work on worksheets in their teams to master the material.
- **Test:** Students take individual quizzes or other assessments (such as essays or performances).
- **Team recognition:** Team scores are computed on the basis of team members' scores, and certificates, a class newsletter, or a bulletin board recognizes high-scoring teams.

The following steps describe how to introduce students to STAD:

1. Assign students to teams of four or five-members each. Four are preferable; make five-member teams only if the class is not divisible by four. To assign the students, rank them from top to bottom on some measure of academic performance (e.g., past grades, test scores) and divide the ranked list into quarters, placing any extra students in the middle quarters. Then put one student from each quarter on each team, making sure that the teams are well balanced in gender and ethnicity. Extra (middle) students may become fifth members of teams.
2. Make a worksheet and a short quiz for the lesson you plan to teach. During team study (one or two class periods) the team members' tasks are to master the material you presented in your lesson and to help their teammates master the material. Students have worksheets or other study materials that they can use to practice the skill being taught and to assess themselves and their teammates.
3. When you introduce STAD to your class, read off team assignments.
   - Have teammates move their desks together or move to team tables, and allow students about 10 minutes to decide on a team name.
   - Hand out worksheets or other study materials (two of each per team).
   - Suggest that students on each team work in pairs or threes. If they are working problems (as in math), each student in a pair or threesome should work the problem and then check with his or her partner(s). If anyone missed a question, that student's teammates have a responsibility to explain it. If students are working on short-answer questions, they might quiz each other, with partners taking turns holding the answer sheet or attempting to answer the questions.
   - Emphasize to students that they are not finished studying until they are sure that all their teammates will make 100 percent on the quiz.
   - Make sure that students understand that the worksheets are for studying—not for filling out and handing in. That is why it is important for

students to have the answer sheets to check themselves and their teammates as they study.

- Have students explain answers to one another instead of just checking each other against the answer sheet.
- When students have questions, have them ask a teammate before asking you.
- While students are working in teams, circulate through the class, praising teams that are working well and sitting in with each team to hear how the members are doing.

4. Distribute the quiz or other assessment, and give students adequate time to complete it. Do not let students work together on the quiz; at this point they must show what they have learned as individuals. Have students move their desks apart if this is possible. Either allow students to exchange papers with members of other teams or collect the quizzes to score after class.
5. Figure individual and team scores. Team scores in STAD are based on team members' improvements over their own past records. As soon as possible after each quiz, you should compute individual team scores, and write a class newsletter (or prepare a class bulletin board) to announce the team scores. If at all possible, the announcement of team scores should be made in the first period after the quiz. This makes the connection between doing well and receiving recognition clear to students, increasing their motivation to do their best. Compute team scores by adding up the improvement points earned by the team members and dividing the sum by the number of team members who are present on the day of the quiz.
6. Recognize team accomplishments. As soon as you have calculated points for each student and figured team scores, you should provide some sort of recognition to any teams that averaged 20 improvement points or more. You might give certificates to team members or prepare a bulletin board display. It is important to help students value team success. Your own enthusiasm about team scores will help. If you give more than one quiz in a week, combine the quiz results into a single weekly score. After 5 or 6 weeks of STAD, reassign students to new teams. This allows students to work with other classmates and keeps the program fresh.

CONNECTIONS

For more on the ILE system, see Chapter 10, page 000.

COOPERATIVE INTEGRATED READING AND COMPOSITION (CIRC) **Cooperative Integrated Reading and Composition (CIRC)** (Stevens & Slavin, 1995a) is a comprehensive program for teaching reading and writing in the upper elementary grades. Students work in four-member cooperative learning teams. They engage in a series of activities with one another, including reading to one another, making predictions about how narrative stories will come out, summarizing stories to one another, writing responses to stories, and practicing spelling, decoding, and vocabulary. They also work together to master main ideas and other comprehension skills. During language arts periods, students engage in writing drafts, revising and editing one another's work, and preparing for publication of team books. Three studies of the CIRC program have found positive effects on students' reading skills, including improved scores on standardized reading and language tests (Stevens et al., 1987; Stevens & Slavin, 1991, 1995a).

Cooperative Integrated Reading and Composition (CIRC)
A comprehensive program for teaching reading and writing in the upper elementary grades; students work in four-member cooperative learning teams.

JIGSAW In **Jigsaw** (Aronson, Blaney, Stephen, Sikes, & Snapp, 1978), students are assigned to six-member teams to work on academic material that has been broken down into sections. For example, a biography might be divided into early life, first accomplishments, major setbacks, later life, and impact on history. Each team member reads his or her section. Next, members of different teams who have studied the same sections meet in expert groups to discuss their sections. Then the students return to their teams and take turns teaching their teammates about their sections. Since the only way students can learn sections other than their own is to listen carefully to their teammates, they are motivated to support and show interest in one another's work. In a modification of this approach called Jigsaw II (Slavin, 1994a), students work in four- or five-member teams, as in STAD. Instead of each student being assigned a unique section, all students read a common text, such as a book chapter, a short story, or a biography. However, each student receives a topic on which to become an expert. Students with the same topics meet in expert groups to discuss them, after which they return to their teams to teach what they have learned to their teammates. The students take individual quizzes, which result in team scores, as in STAD.

LEARNING TOGETHER **Learning Together,** a model of cooperative learning developed by David Johnson and Roger Johnson (1999), involves students working in four- or five-member heterogeneous groups on assignments. The groups hand in a single completed assignment and receive praise and rewards based on the group product. This method emphasizes team-building activities before students begin working together and regular discussions within groups about how well they are working together.

GROUP INVESTIGATION **Group Investigation** (Sharan & Sharan, 1992) is a general classroom organization plan in which students work in small groups using cooperative inquiry, group discussion, and cooperative planning and projects. In this method, students form their own two- to six-member groups. After choosing subtopics from a unit that the entire class is studying, the groups break their subtopics into individual tasks and carry out the activities that are necessary to prepare group reports. Each group then makes a presentation or display to communicate its findings to the entire class.

COOPERATIVE SCRIPTING Many students find it helpful to get together with classmates to discuss material they have read or heard in class. A formalization of this age-old practice has been researched by Dansereau (1985) and his colleagues. In it, students work in pairs and take turns summarizing sections of the material for one another. While one student summarizes, the other listens and corrects any errors or omissions. Then the two students switch roles, continuing in this manner until they have covered all the material to be learned. A series of studies of this **cooperative scripting** method has consistently found that students who study this way learn and retain far more than students who summarize on their own or who simply read the material (Newbern, Dansereau, Patterson, & Wallace, 1994). It is interesting that while both participants in the cooperative pairs gain from the activity, the larger gains are seen in the sections that students teach to their partners rather than in those for which they serve as listeners (Spurlin, Dansereau, Larson, & Brooks, 1984). More recent studies of various forms of peer tutoring find similar results (Fuchs & Fuchs, 1997; King, 1997, 1998).

Jigsaw
A cooperative learning model in which students are assigned to six-member teams to work on academic material that has been broken down into sections for each member.

Learning Together
A cooperative learning model in which students in four- or five-member heterogeneous groups work together on assignments.

Group Investigation
A cooperative learning model in which students work in small groups using cooperative inquiry, group discussion, and cooperative planning and projects, and then make presentations to the whole class on their findings.

cooperative scripting
A study method in which students work in pairs and take turns orally summarizing sections of material to be learned.

Research on Cooperative Learning

Cooperative learning methods fall into two broad categories (Slavin, Hurley, & Chamberlain, in press). One category might be called group study methods (Slavin, 1996b), in which students primarily work together to help one another master a relatively well-defined body of information or skills—what Cohen (1994b) calls "well-structured problems." The other category is often called project-based learning or active learning (Stern, 1996). Project-based learning methods involve students working in groups to create a report, experiment, mural, or other product (Webb & Palinscar, 1996). Project-based learning methods such as those described by Blumenfeld, Marx, Soloway, and Krajcik (1996); Cohen (1994a), Palincsar, Anderson, and David (1993); and Sharan and Sharan (1992) focus on ill-structured problems, which typically have less of a clear expected outcome or instructional objective. Methods of this kind are often referred to as collaborative learning methods (Webb & Palinscar, 1996).

Most research comparing cooperative learning to traditional teaching methods has evaluated group study methods such as STAD, Jigsaw II, CIRC, and Johnson's methods. More than 100 studies have compared achievement of students in such methods to that of students in traditional classrooms over periods of at least 4 weeks (Slavin, 1995a). The results have consistently favored cooperative learning as long as two essential conditions are met. First, some kind of recognition or small reward must be provided to groups that do well so that group members can see that it is in their interest to help their groupmates learn (O'Donnell, 1996). Second, there must be individual accountability. That is, the success of the group must depend on the individual learning of all group members, not on a single group product. For example, groups might be evaluated on the basis of the average of their members' scores on individual quizzes or essays (as in STAD), or students might be individually responsible for a unique portion of a group task (as in Group Investigation). Without this individual accountability there is a danger that one student might do the work of the others, or that some students might be shut out of group interaction because they are thought to have little to contribute (O'Donnell & O'Kelly, 1994; Slavin, 1995a).

CONNECTIONS

For more on how cooperative learning methods benefit the social integration of students with special education needs in the general education classroom, see Chapter 12, page 000.

Studies of cooperative learning methods that incorporate group goals and individual accountability show substantial positive effects on the achievement of students in grades 2 through 12 in all subjects and in all types of schools (Ellis, 2001b; Slavin, 1995a; Slavin, Hurley, & Chamberlain, in press). Effects are similar for all grade levels and for all types of content, from basic skills to problem solving (Qin, Johnson, & Johnson, 1995). Although cooperative learning methods are usually used for only a portion of a student's school day and school year (Antil, Jenkins, Wayne, & Vadasy, 1998), one study found that students in schools that used a variety of cooperative learning methods in almost all subjects for a 2-year period achieved significantly better than did students in traditionally organized schools (Stevens & Slavin, 1995b). These effects were particularly positive for the highest achievers (compared to equally high achievers in the control group) and for the special-education students. Other studies have found equal effects of cooperative learning for high, average, and low achievers and for boys and girls (Slavin, 1995a). There is some evidence that these methods are particularly effective for African American and Latino students (Boykin, 1994; Calderón et al., 1998; Hurley, 2000; Slavin, Hurley, & Chamberlain, in press). More informal cooperative learning methods, lacking group goals and individual accountability, have not generally had positive effects on student achievement (Chapman, 2001; Klein & Schnackenberg, 2000; Slavin, 1995; Slavin et al., in press).

In addition to group goals and individual accountability, a few classroom practices can contribute to the effectiveness of cooperative learning. For example, students in cooperative groups who are taught communication and helping skills (Fuchs, Fuchs, Kazdan, & Allen, 1999; Webb & Farrivar, 1994) or are taught metacognitive learning strategies (Fantuzzo, King, & Heller, 1992; Friend, 2001; Hoek, Terwel, & van den Eeden, 1997; Jones et al., 2000) learn more than do students in usual cooperative groups. For example, King (1999) taught students generic question forms to ask each other as they studied, such as "compare and contrast _______ and _______," or "how does _______ affect _______?" Students in classes that used these discourse patterns learned more than students using other forms of cooperative learning. A great deal of research has shown that students who give extensive explanations to others learn more in cooperative groups than do those who give or receive short answers or no answers (Nattiv, 1994; Webb, 1992; Webb, Trooper, & Fall, 1995).

There is less research on the effects of project-based forms of cooperative learning focused on ill-structured problems; but the studies that do exist show equally favorable results of cooperative methods designed for such problems (Blumenfeld et al., 1996; Lazarowitz, 1995; Thousand & Villa, 1994). In particular, a study by Sharan and Shachar (1988) found substantial positive effects of the Group Investigation method on higher-order objectives in language and literature, and studies by Cohen (1994a) have shown that the more consistently teachers implement her Complex Instruction program, the better children achieve.

In addition to boosting achievement, cooperative learning methods have had positive effects on such outcomes as improved intergroup relations (Slavin, 1995b), self-esteem, attitudes toward school, and acceptance of children with special educational needs (Schmuck & Schmuck, 1997; Shulman, Lotan, & Whitcomb, 1998; Slavin, 1995a; Slavin et al., in press). Studies find that cooperative learning is very widely used (e.g., Antil et al., 1998; Puma et al., 1997), but the forms of cooperative learning most often used are informal methods lacking group goals and individual accountability. If this method is to achieve its full potential, educators will need to focus on more research-based strategies.

SELF-CHECK

INTASC

INTASC Standard 4: Instructional Strategies. A teacher must understand and use a variety of instructional strategies to encourage student development of critical thinking, problem solving, and performance skills.

Explain how each of the following cooperative learning methods encourages student development of critical thinking and problem solving: (1) Jigsaw; (2) Learning Together; (3) Group Investigation; (4) cooperative scripting.

How Are Problem-Solving and Thinking Skills Taught?

Students cannot be said to have learned anything useful unless they have the ability to use information and skills to solve problems. For example, a student might be quite good at adding, subtracting, and multiplying but have little idea of how to solve this problem: "Sylvia bought four hamburgers at $1.25 each, two orders of french fries at 65 cents, and three large sodas at 75 cents. How much change did she get from a 10-dollar bill?"

Teacher Action Checklist

Using Fermi Questions to Teach Math Concepts: Water Balloon Fun

From "Math Forum" (http://mathforum.org)

✔ **Purpose:** To encourage multiple approaches, emphasize process rather than "the answer," and promote nontraditional problem-solving strategies. Fermi questions receive their name from Enrico Fermi, an Italian physicist known for his participation in the Los Alamos atomic bomb project and the development of quantum theory.

✔ **Materials:** Paper or poster board, a large quantity of balloons, a supply of running water, the approval of a very understanding principal and of very supportive parents!

✔ **Procedure:**

1. What could be more fun for middle school students than water balloons? Pose the question to the class: How many water balloons does it take to fill the school gymnasium, auditorium, classroom, and so on?
2. Have students, working in groups of two or three, build a cubic foot container using paper or poster board.
3. Have students approximate the volume of a water balloon.
4. Have students approximate how many water balloons are needed to fill their cubic foot container.
5. Have students investigate measure, or approximate the volume of the room to be filled with water balloons.
6. Have students determine, based on approximations in steps 1–4, the approximate number of water balloons that would be needed to fill the room or gym.
7. Then for the real fun . . . let students test out their approximations. Allow students to fill their cubic foot container with water balloons. Have students keep a record of how many water balloons they place in the container. Allowing for varying amounts of water in balloons, calculate the "average number of balloons" per cubic foot of water.

Source: Adapted from "Fermi Questions—Classroom Activities" at http://mathforum.org/ workshops/sum96/ interdisc/classactivity.html. Reprinted with permission of The Math Forum @ Drexel, and online community for mathematics education <http://mathforum.org/>. © 1996, The Math Forum @ Drexel.

Sylvia's situation is not an unusual one in real life, and the computations involved are not difficult. However, many students (and even some otherwise competent adults) would have difficulty solving this problem. The difficulty of most applications problems in mathematics lies not in the computations but in knowing how to set the problem up so that it can be solved. **Problem solving** is a skill that can be taught and learned (Bransford & Stein, 1993; Martinez, 1998; Mayer & Wittrock, 1996).

problem solving
The application of knowledge and skills to achieve certain goals.

The Problem-Solving Process

GENERAL PROBLEM-SOLVING STRATEGIES Students can be taught several well-researched strategies to use in solving problems (see, for example, Beyer, 1998;

Derry, 1991; Tishman, Perkins, & Jay, 1995). Bransford and Stein (1993) developed and evaluated a five-step strategy called IDEAL:

I Identify problems and opportunities
D Define goals and represent the problem
E Explore possible strategies
A Anticipate outcomes and act
L Look back and learn

IDEAL and similar strategies begin with careful consideration of what problem needs to be solved, what resources and information are available, and how the problem can be represented (e.g., in a drawing, outline, or flowchart) and then broken into steps that lead to a solution. For example, the first step is to identify the goal and figure out how to proceed. Newell and Simon (1972) suggest that the problem solver repeatedly ask, "What is the difference between where I am now and where I want to be? What can I do to reduce that difference?" In solving Sylvia's problem, the goal is to find out how much change she will receive from a 10-dollar bill after buying food and drinks. We might then break the problem into substeps, each with its own subgoal:

1. Figure how much Sylvia spent on hamburgers.
2. Figure how much Sylvia spent on french fries.
3. Figure how much Sylvia spent on sodas.
4. Figure how much Sylvia spent in total.
5. Figure how much change Sylvia gets from $10.00.

means–ends analysis
A problem-solving technique that encourages identifying the goal (ends) to be attained, the current situation, and what needs to be done (means) to reduce the difference between the two conditions.

MEANS–ENDS ANALYSIS Deciding what the problem is and what needs to be done involves a **means–ends analysis.** Learning to solve problems requires a great deal of practice with different kinds of problems that demand thought. All too often,

What steps should these students take to successfully solve the problem?

textbooks in mathematics and other subjects that include many problems fail to present problems that will make students think. For example, they might give students a set of word problems whose solutions require the multiplication of two numbers. Students soon learn that they can solve such problems by looking for any two numbers and multiplying them. In real life, however, problems do not line themselves up neatly in categories. We might hear, "Joe Smith got a 5 percent raise last week, which amounted to $1,200." If we want to figure out how much Joe was making before his raise, the hard part is not doing the calculation, but knowing what calculation is called for. In real life this problem would not be on a page titled "Dividing by Percents." The more different kinds of problems students learn to solve, and the more they have to think to solve the problems, the greater the chance that, when faced with real-life problems, students will be able to transfer their skills or knowledge to the new situation.

EXTRACTING RELEVANT INFORMATION Realistic problems are rarely neat and tidy. Imagine that Sylvia's problem was as follows:

> Sylvia walked into the fast-food restaurant at 6:18 with three friends. Between them, they bought four hamburgers at $1.25 each, two orders of french fries at 65 cents, and three large sodas at 75 cents. Onion rings were on sale for 55 cents. Sylvia's mother told her to be in by 9:00, but she was already 25 minutes late by the time she and her friends left the restaurant. Sylvia drove the 3 miles home at an average of 30 miles per hour. How long was Sylvia in the restaurant?

The first part of this task is to clear away all the extraneous information to get to the important facts. The means–ends analysis suggests that only time information is relevant, so all the money transactions and the speed of Sylvia's car can be ignored. Careful reading of the problem reveals that Sylvia left the restaurant at 9:25. This and her arrival time of 6:18 are all that matters for solving the problem. Once we know what is relevant and what is not, the solution is easy.

REPRESENTING THE PROBLEM For many kinds of problems, graphic representation might be an effective means of finding a solution. Adams (1974) provides a story that illustrates this:

> A Buddhist monk has to make a pilgrimage and stay overnight in a temple that is at the top of a high mountain. The road spirals around and around the mountain. The monk begins walking up the mountain at sunrise. He walks all day long and finally reaches the top at about sunset. He stays all night in the temple and performs his devotions. At sunrise the next day the monk begins walking down the mountain. It takes him much less time than walking up, and he is at the bottom shortly after noon. The question is: Is there a point on the road when he was coming down that he passed at the same time of day when he was coming up the mountain?

This can seem to be a difficult problem because people begin to reason in a variety of ways as they think about the man going up and down. Adams points out one representation that makes the problem easy: Suppose there were two monks, one leaving the top at sunrise and one starting up at sunrise. Would they meet? Of course they would.

In addition to drawings, there are many other ways of representing problems. Students may be taught to make diagrams, flowcharts, outlines, and other means of summarizing and depicting the critical components of a problem (Katayama & Robinson, 1998; Robinson & Kiewra, 1995; van Meter, 2001).

TECHNOLOGY CASE STUDY

Multiple Representations

Karen Zdanis is a teacher at Livingston Elementary School.

"Technology helps me provide students with multiple representations of concepts and allows students to manipulate objects and ideas. For example, when I teach fractions in my math class my students use [the computer program] Excel to manipulate numbers which, in turn, manipulate graphs and charts. They get to see the relationship of the numerator to the denominator and then they see the graphic representation of the same thing. I like to use pie charts to look at individual fractions and then graphs to look at patterns of fractions. Seeing multiple representations and manipulating the objects really helps students encode the information into their long-term memory." ■

Teaching Creative Problem Solving

Most of the problems students encounter in school might require careful reading and some thought, but little creativity. However, many of the problems we face in life are not so cut-and-dried. Life is full of situations that call for creative problem solving, as in figuring out how to change or end a relationship without hurt feelings or how to repair a machine with a bent paper clip (Sternberg, 1995).

The following sections describe a strategy for teaching creative problem solving (Beyer, 1997; Frederiksen, 1984a; Perkins, 2000).

INCUBATION Creative problem solving is quite different from the analytical, step-by-step process that was used to solve Sylvia's problems. In creative problem solving, one important principle is to avoid rushing to a solution; instead, it is useful to pause and reflect on the problem and think through, or incubate, several alternative solutions before choosing a course of action. Consider the following simple problem:

> Roger baked an apple pie in his oven in three quarters of an hour. How long would it take him to bake three apple pies?

Many students would rush to multiply 45 minutes by 3. However, if they took some time to reflect, most would realize that baking three pies in the same oven would actually take about the same amount of time as baking one pie! In teaching this process, teachers must avoid putting time pressures on students. Instead of speed, they should value ingenuity and careful thought.

SUSPENSION OF JUDGMENT In creative problem solving, students should be encouraged to suspend judgment, to consider all possibilities before trying out a solution. One specific method based on this principle is called *brainstorming* (Osborn, 1963), in which two or more individuals suggest as many solutions to a problem as they can think of, no matter how seemingly ridiculous. Only after they have thought of as many ideas as possible is any idea evaluated as a possible solution.

The point of brainstorming is to avoid focusing on one solution too early and perhaps ignoring better ways to proceed.

APPROPRIATE CLIMATES Creative problem solving is enhanced by a relaxed, even playful environment (Tishman et al., 1995). Perhaps even more important, students who are engaging in creative problem solving must feel that their ideas will be accepted.

People who do well on tests of creative problem solving seem to be less afraid of making mistakes and appearing foolish than do those who do poorly. Successful problem solvers also seem to treat problem-solving situations more playfully (Benjafield, 1992). This implies that a relaxed, fun atmosphere is important in teaching problem solving. Students should certainly be encouraged to try different solutions and not be criticized for taking a wrong turn.

ANALYSIS One method of creative problem solving that is often suggested is to analyze and juxtapose major characteristics or specific elements of a problem (Chen & Daehler, 2000; Lesgold, 1988). For example, careful analysis of the situation might help solve the following problem:

> A tennis tournament was set up with a series of rounds. The winner of each match advanced to the next round. If there were an odd number of players in a round, one player (chosen at random) would advance automatically to the next round. In a tournament with 147 players, how many matches would take place before a single winner would be declared?

We might solve this problem the hard way, making diagrams of the various matches. However, careful analysis of the situation would reveal that each match would produce exactly one loser. Therefore it would take 146 matches to produce 146 losers (and one winner).

ENGAGING PROBLEMS One key to teaching of problem solving is providing problems that intrigue and engage children. The same problem solving skills could be involved in a context that is either compelling or boring to students, and this matters in the outcomes. For example, Bottge (2001) found that low-achieving secondary students, many with serious learning disabilities, could learn complex problem solving skills relating to building a cage for a pet or setting up a car racing track. Since John Dewey proposed it a hundred years ago, the motivational value of connecting problem solving to real life or simulations of real life has been demonstrated many times (Holt & Willard-Holt, 2000; Torp & Sage, 1998; Westwater & Wolfe, 2000).

FEEDBACK Provide practice with feedback. Perhaps the most effective way to teach problem solving is to provide students with a great deal of practice on a wide variety of problem types, giving feedback not only on the correctness of their solutions but also on the process by which they arrived at the solutions (Swanson, 1990). The role of practice with feedback in solving complex problems cannot be overemphasized. Mr. Dunbar's students, in the chapter-opening vignette, could not have arrived at the solution to their problem if they had not had months of practice and feedback on simpler problems.

Teaching Thinking Skills

One of the oldest dreams in education is that there might be some way to make students smarter—not just more knowledgeable or skillful but actually better able to

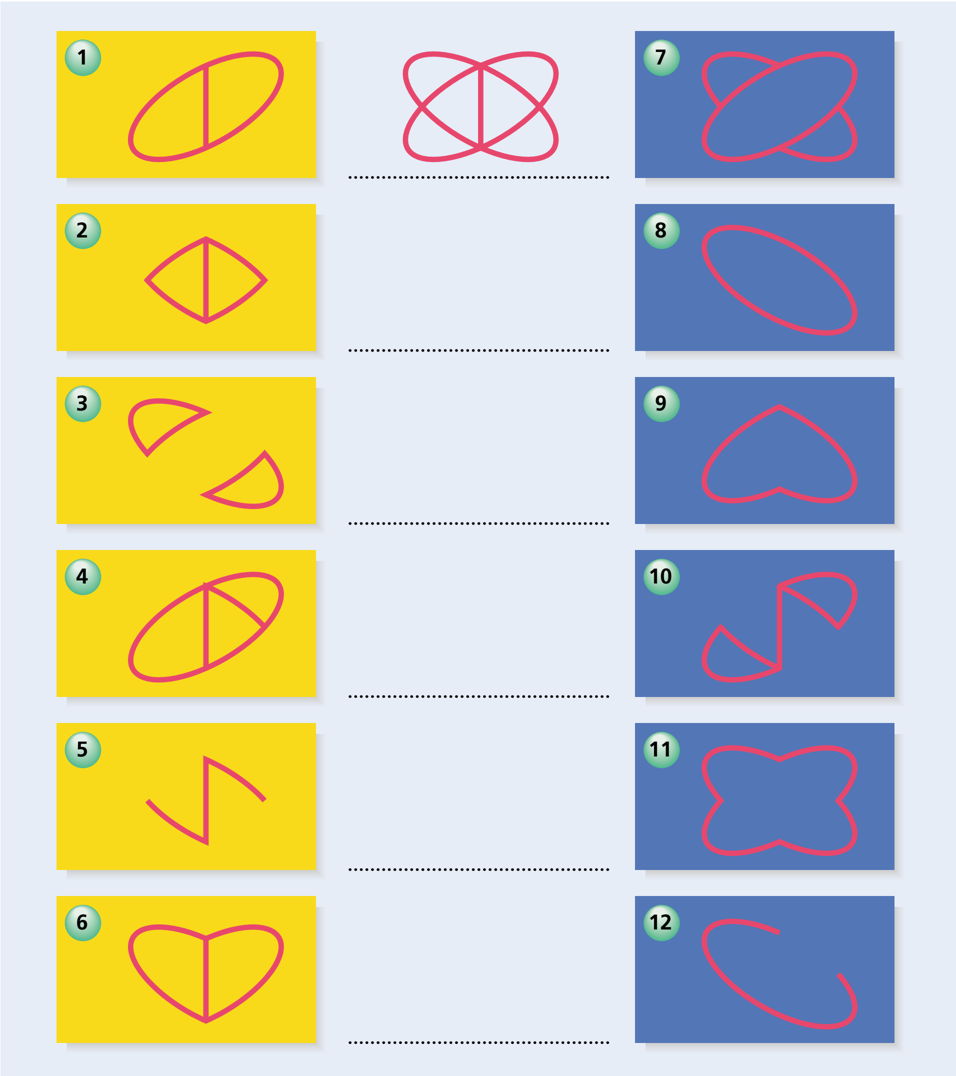

FIGURE 8.4 Examples from Analytic Perception
Look at the three columns at the right. For each drawing in the left column, there is a drawing in the right column that completes it to make the form shown in the middle column. Write the number of the form in the right column needed to complete the form in the first column. The student must select the appropriate drawing from the right to complete the one on the left to obtain a figure identical to the model in the middle column on this page. The task requires representation, internalization and labeling of the model, definition of the missing parts, systematic work, and comparison to the model for self-criticism.

From Reuven Feuerstein, "Instrumental Enrichment: A Selected Sample of Material for Review Purposes." Jerusalem: The Hadassah-Wizo-Canada Research Institute, May 1973, p. 5. Reprinted by permission of the author.

ED: Images in 3rd col do not show up in black-n-white printout, but they are fine in color proof.

learn new information of all kinds (Beyer, 1998). Perhaps someday someone will come up with a "smart pill" that will have this effect; but in the meantime, several groups of researchers have been developing and evaluating instructional programs that are designed to increase students' general thinking skills.

The most widely known and extensively researched of several thinking-skills programs that are currently in use was developed by an Israeli educator, Reuven Feuerstein (1980). In this program, called **Instrumental Enrichment,** students work through a series of paper-and-pencil exercises that are intended to build such intellectual skills as categorization, comparison, orientation in space, and numerical progressions. Figure 8.4 shows one example of an activity designed to increase analytic perception. The Instrumental Enrichment treatment is meant to be administered for 3 to 5 hours per week over a period of at least 2 years, usually to underachieving or learning-disabled adolescents. Studies of this duration have found that the program has positive effects on tests of aptitude, such as IQ tests, but generally not on achievement (Savell, Twohig, & Rachford, 1986; Sternberg & Bhana,

Instrumental Enrichment
A thinking skills program in which students work through a series of paper-and-pencil exercises that are designed to develop various intellectual abilities.

1986). Less intensive interventions, particularly those involving fewer than 80 hours of instruction, have rarely been successful. In one study done in Israel (Feuerstein et al., 1981) and one in Venezuela (Ruiz, 1985), positive effects of Instrumental Enrichment on aptitude test scores were still found 2 years after the program ended. Many reviewers of the research on Instrumental Enrichment have suggested that this method is simply teaching students how to take IQ tests rather than teaching them anything of real value (Sternberg & Bhana, 1986). Many of the exercises (such as the one reproduced in Figure 8.4) are, in fact, quite similar to items that are used in nonverbal IQ tests. A similar pattern of results has been found for many other thinking-skills programs (Adams, 1989). In fact, researchers have now begun to question whether there are broadly applicable thinking skills—the evidence points more toward the existence of teachable thinking skills in specific domains, such as math problem solving or reading comprehension (Perkins & Salomon, 1989). In fact, researchers have combined teaching of thinking skills with instruction in specific content areas, and results of these combined models are more encouraging (Adams, 1989; Bellanca, 1998; Derry & Murphy, 1986; Prawat, 1991).

Another approach to the teaching of thinking skills is to incorporate them in daily lessons and classroom experiences—to create a "culture of thinking" (Tishman et al., 1995; Sternberg, 1998). As an example of integrating thinking skills into daily lessons, Tishman, Perkins, and Jay (1995) describe an impromptu discussion in a class that has been taught a generic strategy for problem solving. This strategy is built around a four-step process (state, search, evaluate, and elaborate) that is summarized in Table 8.2. In their example, Ms. Mandly's sixth-graders discuss why plants in terrariums the class planted a month earlier are starting to die and what they might do about it. The class learned the steps summarized in Table 8.2 and had a poster identical to the table posted in the classroom. The discussion went as follows:

Ms. Mandly: Let's take a look at the poster. How can we build a strategy to deal with this situation? Which building blocks can we use?

Rory: We should use the search step, to search for a solution to the problem.

Marc: Yeah, but we're not even exactly sure what the problem is. We don't know if the plants in the terrarium are wilted because they have too much water or too little.

Ms. Mandly: Are you suggesting we also need a state step, Marc?

Marc (after a moment of looking at the poster): Yes. In two ways: I think we need to state the problem and we need to state our goal.

Ms. Mandly: That sounds reasonable. Any other building blocks we can use?

Marc: Yeah, that might not be enough. What if you take care of a terrarium, and it still wilts? Other people in your group will want to know what went wrong.

Ms. Mandly: It sounds like we have two goals here. One, decide how to care for the terrarium. And two, make a plan for keeping track of the terrarium's care.

After more discussion, students agreed on exactly what outcomes they wanted and moved to the "search" step. Looking at the search tactics, they decided to brainstorm lots of different possible solutions. Ms. Mandly kept track of their ideas on the blackboard and occasionally reminded them to keep in mind some key tactics: to look for hidden ideas and to look for different kinds of ideas. Some of the ideas students came up with are the following:

1. Have a sign-up list.
2. Let the teacher decide who should water.
3. Have one person volunteer to do it all.

TABLE 8.2

Thinking Skills: Build a Strategy

STRATEGY BUILDING BLOCKS		
WHEN . . .	**STRATEGY STEP**	**TACTICS**
When you need to be clear about what you're doing or where you're going . . .	**State . . .** either the problem, the situation, or your goal(s).	Identify the different dimensions of the situation. Identify the parts of the situation you will focus on. State precisely what you want to change or what you want your outcome to be. Be specific!
When you need to think broadly about something . . .	**Search . . .** for ideas, options, possibilities, purposes, features, assumptions, causes, effects, questions, dimensions, hypotheses, facts, or interpretations.	Brainstorm. Look for different kinds of ideas. Look at things from different points of view. Look for hidden ideas. Build on other people's ideas. Use categories to help you search.
When you need to assess, rate, or decide something . . .	**Evaluate . . .** options, plans, ideas, theories, or objects.	Look for lots of reasons. Consider the immediate and long-term consequences. List all the pros and cons, paying attention to both. Try to be objective; avoid bias. Use your imagination: How will it affect others?
When you need to think about the details of something . . .	**Elaborate . . .** possibilities, plans, options, hypotheses, or ideas.	Make a detailed plan: Say what will happen at each step. Visualize what it will look/feel/seem like *in detail.* Ask yourself: What resources will be used? How will it happen? Who will be affected? How long will it take? Think about the different parts. Draw a picture or write a description; imagine *telling* someone about it.

Source: From Shari Tishman, David N. Perkins, and Eileen Jay, *The Thinking Classroom.* Copyright © 1995 by Allyn & Bacon. Reprinted by permission.

4. Make a rotating schedule for each group.
5. Make a rotating schedule, plus have weekly group meetings to discuss progress.

After students reviewed and evaluated their brainstormed list, they unanimously agreed that option 5—rotating schedule plus weekly meetings—was best.

They then went on to step 4: elaborate, and make a plan. They designed a rotation schedule for each terrarium group, and with Ms. Mandly's help they picked a time for weekly group meetings. Working through the "elaborate step,"

THE INTENTIONAL TEACHER

Using What You Know about Student-Centered and Constructivist Approaches to Improve Teaching and Learning

Intentional teachers keep sight of one of the overarching goals of education: to foster students' ability to solve real, complex problems. Intentional teachers work toward this lofty goal by ensuring that schooling provides more than a series of lectures and discrete workbook exercises. Intentional teachers furnish opportunities for students to build their own knowledge, to work with others in discovering important ideas, and to attack challenging issues.

1 What do I expect my students to know and to be able to do at the end of this lesson? How does this contribute to course objectives and to students' need to become capable individuals?

Intentional teachers build in regular opportunities for students to approach complex, difficult, realistic tasks. Check your goals and curriculum: Where and how often do you encourage students to construct knowledge through student-centered approaches? For example, you might provide regular opportunities for students to study and use mathematics in realistic settings. The class might, for instance, develop, administer, analyze, and act on a schoolwide survey about a current issue, such as the purchase of playground equipment.

Intentional teachers think about the balance between direct, teacher-centered instructional approaches and constructivist, student-centered approaches. Select your teaching strategies based on your goals for students, and realize that a balance of both kinds of approaches might be best for promoting a variety of learning outcomes. For example, imagine that you feel pressed to cover a great deal of information in your government class; as a result, you find yourself lecturing almost daily. Then you recall that your major goal is to help your students become citizens who make informed decisions about complicated issues. Therefore, you review your plan book to ensure that you are using discovery approaches regularly. You begin with a discovery lesson the very next day by distributing nickels and asking students to draw inferences about the culture that created them.

2 What knowledge, skills, needs, and interests do my students have that must be taken into account in my lesson?

Background knowledge affects students' ability to build meaning and solve problems. Gather information about your students' earlier school experiences by conversing with last year's teacher or teachers: Do your learners come with previous experiences in group work? What do their records suggest about their preferences and attitudes toward novelty?

Intentional teachers make use of top-down processing by beginning instruction with holistic problems or issues and moving to analysis of their parts. You might begin your lessons with real problems within the context of a supportive atmosphere. For example, you might begin a math class with a question: "If there are five flavors of fruity candies in this bag, how many flavor combinations can I create?" You could note the students' widely varying initial guesses, and then pass out bags of candy and allow them to get to work on the problem. When it becomes evident that they are stymied, you could suggest that they try a charting strategy to work on a single part of the problem: How many combinations of *just two* flavors are there? You and your class could devise the chart below, quickly finding patterns and discovering that there are 10 flavor combinations of two candies. Students should discern that they simply need to make similar chart for 3-, 4-, and 5-flavor combinations to arrive at their answer.

Flavor 1	~~1-1~~ 1-2 1-3 1-4 1-5 (symbols represent flavor 1 with flavors 2, 3, 4, and 5)
Flavor 2	~~2-1 2-2~~ 2-3 2-4 2-5
Flavor 3	~~3-1 3-2 3-3~~ 3-4 3-5
Flavor 4	~~4-1 4-2 4-3 4-4~~ 4-5
Flavor 5	~~5-1 5-2 5-3 5-4 5-5~~

Teach strategies for problem-solving: include drawing pictures, acting out situations, and making diagrams. Model a variety of problem-solving strategies, using them as scaffolds to keep students working within their zone of proximal development.

3 What do I know about the content, child development, learning, motivation, and effective teaching strategies that I can use to accomplish my objectives?

As students work on a cooperative project, watch them. What does their nonverbal behavior tell you about how well they are working with peers? How willing are they to take risks? When you see that students are unwilling to accept peers' ideas, you might stop the lesson and provide instruction on working well with others: "When someone gives a new idea, wait before you say no. Think for twenty seconds about how that idea might work. Watch, I'll pretend I'm in your group and you tell me a new idea. . . ."

4 What instructional materials, technology, assistance, and other resources are available to help accomplish my objectives?

Emotion, personal meaning, and relevance can help students process information deeply so that they remember better. Begin your lesson in ways that capture student interest, and provide instruction that focuses on developing understanding beyond surface-level features.

You begin a lesson on density by displaying two bottles of soda (one full, one with some air in it) in an aquarium: One sinks, but the other floats! The students' curiosity is piqued and they actively engage themselves in discovering the rule that allows for the cans' behavior. At the lesson's close, you create a powerful visual image of an immense iceberg floating in the chilling sea. You ask students to explain, using their new understading of density, why the iceberg floats despite its vast size.

Your discussions with colleagues, both in the current setting in which you work, and with former classmates, can serve to help you identify new materials and other resources that will benefit your efforts to become a more intentional, student-centered teacher.

5 How will I plan to assess students' progress toward my objectives?

Students' outputs provide information about success. Examine students' work for evidence of sense-making, of critical thinking, and of creativity. Imagine that you've just collected a stack of essays on students' analysis of a current environmental issue: destruction of the rain forests. You might begin your assessment by listing two questions to help you focus on students' knowledge construction: (a) How well do students marshal factual details to support their position? (b) What evidence is there of creative, inventive thinking?

One of the most challenging aspects of a student-centered orientation to teaching is how to determine whether students have met learning goals and attained intended objectives. Assess your instruction using multiple measures.

Review your plan book and check to see how many realistic opportunities you provided in the last week. Audio or videotape yourself teaching and analyze the kinds of questions and prompts you use. Ask your students for feedback on your teaching, using survey questions like this one: "The teacher __________ [never/sometimes/often/always] gives us opportunities to figure things out on our own."

6 How will I respond if individual children or the class as a whole are not on track toward success? What is my back-up plan?

How can you, as an intentional teacher seeking to incorporate constructivist approaches, help prepare your students for this change from "tell me what I'm supposed to do" to the practices of group learning, inquiry, and open-ended thinking?

To help your students become more self-directed, not only utilize cooperative approaches wherever possible, but also provide direct instruction in helping and communication skills at the start of cooperative learning lessons. You can provide instruction on how to give feedback in group work, recalling that research has shown that students who give and/or receive extensive explanations learn more in cooperative settings. These techniques will help students to reach group goals.

they invented a detailed checklist for the designated weekly waterer, to help track factors that might contribute to the terrarium's health, such as how much water has been given, the date of watering, the temperature of the classroom, and so on (Tishman et al., 1995).

In the course of discussing the terrarium problem, the students were learning a broadly applicable strategy for approaching and solving complex problems. By calling on this and other strategies frequently as they are appropriate in a classroom context, Ms. Mandly not only gave students useful strategies but also communicated the idea that strategy use is a normal and expected part of daily life.

Critical Thinking

One key objective of schooling is enhancing students' abilities to think critically, to make rational decisions about what to do or what to believe (Marzano, 1995). Examples of **critical thinking** include identifying misleading advertisements, weighing competing evidence, and identifying assumptions or fallacies in arguments. As with any other objective, learning to think critically requires practice; students can be given many dilemmas, logical and illogical arguments, valid and misleading advertisements, and so on (Halpern, 1995). Effective teaching of critical thinking depends on setting a classroom tone that encourages the acceptance of divergent perspectives and free discussion. There should be an emphasis on giving reasons for opinions rather than only giving correct answers. Skills in critical thinking are best acquired in relation to topics with which students are familiar. For example, students will learn more from a unit evaluating Nazi propaganda if they know a great deal about the history of Nazi Germany and the culture of the 1930s and 1940s. Perhaps most important, the goal of teaching critical thinking is to create a critical spirit, which encourages students to question what they hear and to examine their own thinking for logical inconsistencies or fallacies.

Beyer (1988) identified 10 critical-thinking skills that students might use in judging the validity of claims or arguments, understanding advertisements, and so on:

1. Distinguishing between verifiable facts and value claims
2. Distinguishing relevant from irrelevant information, claims, or reasons
3. Determining the factual accuracy of a statement
4. Determining the credibility of a source
5. Identifying ambiguous claims or arguments
6. Identifying unstated assumptions
7. Detecting bias
8. Identifying logical fallacies
9. Recognizing logical inconsistencies in a line of reasoning
10. Determining the strength of an argument or claim. (p. 57)

Beyer notes that this is not a sequence of steps but rather a list of possible ways in which a student might approach information to evaluate whether or not it is true or sensible. The key task in teaching critical thinking to students is to help them learn not only how to use each of these strategies but also how to tell when each is appropriate.

critical thinking
The ability to make rational decisions about what to do or what to believe.

SELF-CHECK

INTASC

INTASC Standard 4: Instructional Strategies. A teacher must understand and use a variety of instructional strategies to encourage student development of critical thinking, problem solving, and performance skills.

Explain how Mr. Dunbar, the teacher in the chapter-opening vignette, incorporates the problem-solving process into his lesson. Give an example of an obstacle to problem solving that the students in Mr. Dunbar's class face.

CHAPTER SUMMARY

WHAT IS THE CONSTRUCTIVIST VIEW OF LEARNING?

Constructivists believe that knowing is a process and that learners must individually and actively discover and transform complex information to make it their own. Constructivist approaches emphasize top-down processing, in which students begin with complex problems or tasks and discover the basic knowledge and skills needed to solve the problems or perform the tasks. Constructivist approaches also emphasize cooperative learning, questioning or inquiry strategies, and other metacognitive skills.

Discovery learning and scaffolding are constructivist learning methods based on cognitive learning theories. Bruner's discovery learning highlights students' active self-learning, curiosity, and creative problem solving. Scaffolding, based on Vygotsky's views, calls for teacher assistance to students at critical points in their learning.

HOW IS COOPERATIVE LEARNING USED IN INSTRUCTION?

In cooperative learning, small groups of students work together to help one another learn. Cooperative learning groups are used in discovery learning, discussion, and study for assessment. Cooperative learning programs such as Student Teams–Achievement Divisions (STAD) are successful because they reward both group and individual effort and improvement and because groups are responsible for the individual learning of each group member.

HOW ARE PROBLEM-SOLVING AND THINKING SKILLS TAUGHT?

Problem-solving skills are taught through a series of steps, including, for example, means-ends analysis and problem representation. Creative problem solving requires incubation time, suspension of judgment, conducive climates, problem analysis, the application of thinking skills, and feedback. Thinking skills include, for example, planning, classifying, divergent thinking, identifying assumptions, identifying misleading information, and generating questions. Thinking skills can be taught through programs such as Instrumental Enrichment; creating a culture of thinking in the classroom is another useful technique.

DRAFT

KEY TERMS

cognitive apprenticeship 00
constructivist theories of learning 00
Cooperative Integrated Reading and Composition (CIRC) 00
cooperative learning 00
cooperative scripting 00
critical thinking 00
discovery learning 00
Group Investigation 00
Instrumental Enrichment 00
Jigsaw 00
Learning Together 00
means–ends analysis 00
mediated learning 00
problem solving 00
reciprocal teaching 00
self-regulated learners 00
Student Teams–Achievement Divisions (STAD) 00

Self-Assessment

PRAXIS II: PRINCIPLES OF TEACHING AND LEARNING

TOPIC I: Organizing Content Knowledge for Student Learning. Create or select teaching methods, learning activities, and instructional materials or other resources that are appropriate for the students and are aligned with the goals of the lesson.

TOPIC III: Teaching for Student learning. Make learning goals and instructional procedures clear to students.

Directions: The chapter-opening vignette addresses indicators that make up sections for TOPICS I and III of PRAXIS II: Principles of Teaching and Learning. Re-read the chapter-opening vignette, and then respond to the following questions.

1. Mr. Dunbar, in his lesson on the volume of a cylinder, asks his students to figure out how to measure volume through experimentation. What type of learning strategy is he using?
- **a.** direct instruction
- **b.** classical conditioning
- **c.** discovery learning
- **d.** teacher-mediated discussion

2. Why didn't Mr. Dunbar just tell his students that the formula for finding the volume of a cylinder is $\Pi r^2 h$?
- **a.** He believes that students will gain deeper understanding if they work it out for themselves.
- **b.** He thought the lesson would take less time if the students could figure it out.
- **c.** He knows that discovery learning is superior to direct instruction.
- **d.** He is applying teaching strategies suggest by B. F. Skinner and other behaviorists.

3. In which of the following examples is Mr. Dunbar demonstrating Vygotsky's "zone of proximal development" concept?
- **a.** Mr. Dunbar says, "Today we are going to have a chance to discover how to compute the volume of a cylinder."
- **b.** Mr. Dunbar assigns his students to sit around the lab tables in groups of four.
- **c.** Mr. Dunbar, as he is passing by the Master Minds group, says, "You're right, Miguel, but what are you going to do with that information?"
- **d.** Mr. Dunbar praises the Master Minds group for figuring out the answer on their own.

4. Mr. Dunbar effectively uses cooperative learning strategies in his lesson on the volume of cylinders. He does all of the following except
- **a.** give recognition to the groups when they solve the problem.
- **b.** assure that each group contains members who have similar abilities.
- **c.** make certain that each group member learns.
- **d.** mixes students in terms of race, ethnicity, gender, and special needs.

5. Which of the following cooperative learning strategies is Mr. Dunbar using?

a. Group Investigation
b. Learning Together
c. Jigsaw
d. STAD

6. Describe an example of discovery learning. What is the teacher's role in a discovery lesson? What strengths and limitations exist with discovery learning?

7. How can teachers improve students' problem-solving abilities?

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