Cognition and Instruction

Gina Brown decided to use an exercise with her educational psychology class to give students experience with problem-based and discovery learning. She divided the class into small groups and gave them the following problem to solve:

A party of five good guys is on one bank of a river and a party of five bad guys is on the other, and each group wishes to cross to the opposite side. The only means of transportation is a dugout canoe that will hold just three persons. Only one good guy and one bad guy know how to paddle. Moreover, it is unwise for the bad guys to outnumber the good guys in the boat or on either shore. How is it possible for the two parties to cross the stream safely?

One group was composed of Tina, Mike, Tim, and Syd. Their conversation went like this:

Mike: Oh this isn't too hard. I remember doing this problem some years ago. I recall you can do it in a couple of steps. Let's see, first we send over three bad guys, and then bring back a bad guy and two good guys.

Syd: Hold it Mike. When the bad guy and two good guys get back, the bad guys will outnumber the good guys.

Tim: Yeah, that's right. That won't work.

Mike: Well maybe this was more complicated than I thought. Maybe at first you send over two bad guys.

Tina: And then? This is confusing!

Mike: If we leave them there we can send back three good guys. Then the good guys won't be outnumbered.

Tim: We'd have to leave two and two and send back one and one.

Tina: And the rowers. Never put the two rowers together, because we don't need them in the boat at the same time. At least that much I understand!

Mike: Yeah, that'll work. We keep balancing the sides with only one rower in the boat at a time. Oh yeah, this is a lot more complicated.

Tim: At the end we'll have most of the bad guys on one side and then on the last trip it'll be bad guys coming back in the boat.

Mike: Yeah, that's right. Here, let me start writing down each step. Let's be sure to check that we don't have the good guys outnumbered at any time.

This chapter discusses instruction from a cognitive and constructivist perspective. Instructional theory and research have changed dramatically over the years. Historically, researchers have examined topics such as behavioral objectives and programmed learning (Chapter 2). As the influence of conditioning theories declined, researchers began to study the impact of learner, instructional, and contextual variables on one another and on learning in educational settings. Current instructional research investigates topics such as the influence of instructional variables on learners' cognitions, the role of individual differences in learning, and the interrelation of instructional and motivational variables during learning (Glaser, 1990), as well as how learners construct their understandings. As technology becomes increasingly infused in instruction, researchers are examining how technological applications affect the design and delivery of instruction, the interactions among teachers and learners, and the ways that learners think about content, learning environments, and themselves (Jonassen, Peck, & Wilson, 1999).

This chapter builds on the preceding three. In Chapter 4, the components of cognitive information processing were discussed: attention, perception, encoding, memory, retrieval, and forgetting. Chapter 5 covered cognitive processes directly involved in learning: metacognition, concepts, problem solving, and transfer. Chapter 6 was devoted to constructivism. Now we examine theories and models of instruction and instructional research that include cognitive processes.

The chapter begins by reviewing two cognitive perspectives that have been widely applied in classrooms: discovery learning and meaningful reception learning. These perspectives are historical, in the sense that they preceded the cognitive viewpoints currently favored in education; they are, however, still much in vogue today.

We then review the instructional theory of Robert Gagné, which is one of the best known and most commonly applied. We see how Gagné's conditions of learning capture many learning principles discussed throughout this text. Following this section, some other instructional models are presented, along with their implications for teaching and learning. The remaining sections of the chapter address research on teaching, learner characteristics, and technology and instruction.

The field of instructional technology has expanded greatly in recent years, and each advance in technology raises a question of how it affects learning. Technology is not a theory, nor is it necessarily cognitive in orientation; programmed instruction (Chapter 2) is a behavioral method that employs technology. Nonetheless, most researchers exploring technology in education hold a cognitive (and often constructivist) perspective and attempt to explain learning in terms of cognitive information processing. Readers interested in instructional design and implications for learning should consult sources that discuss these topics in greater depth (Ertmer & Newby, 1993; Grabe & Grabe, 1998a; Jonassen, 1996; Roblyer, 2006; Winn, 1990, 2002).

Chapter 1 included a section on the relation of learning and instruction, which stated that different theoretical perspectives on instruction share certain commonalities (see Table 1.4):

- learners progress through stages or phases;
- material should be organized and presented in small steps;
- learners require practice, feedback, and review;
- social models facilitate learning and motivation;
- motivational and contextual factors influence learning.

Theories differ in the amount of emphasis they place on each of these, but the assumptions and principles of instructional theories address each point to some degree. Furthermore, each point is both intuitively plausible and substantiated by research.

When you finish studying this chapter, you should be able to do the following:

- Compare and contrast discovery learning and meaningful reception learning.
- Explain the major components of Gagné's instructional theory: learning outcomes, events, hierarchies, and phases.
- Describe the major assumptions and principles of instructional models: Carroll's time model, mastery learning, inquiry teaching, worked examples, cognitive load, and peer-assisted learning.
- Summarize what research has identified as effective teacher practices in planning and instruction.
- Define aptitude–treatment interactions (ATIs) and explain how these interactions are important for learning.
- Describe some cognitive styles of learners and what they imply for instruction.
- Discuss the major functions of technology and some ways that technology has been infused into instruction.

DISCOVERY LEARNING

The Process of Discovery

Discovery learning refers to obtaining knowledge for oneself (Bruner, 1961). Discovery is important for cognitive learning—especially of complex forms—because it involves constructing and testing hypotheses rather than simply reading or listening to teacher presentations. Discovery is a type of *inductive reasoning,* because students move from studying specific examples to formulating general rules, concepts, and principles. Discovery learning also goes by other names such as problem-based, inquiry, experiential, and constructivist learning (Kirschner et al., 2006).

Discovery is a form of problem solving (Klahr & Simon, 1999; see Chapter 5); it is not simply letting students do what they want. Although discovery is a minimally guided instructional approach, it still involves direction; teachers arrange activities in which students search, manipulate, explore, and investigate. The opening scenario represents a discovery situation. Students learn new knowledge relevant to the domain and such general problem-solving skills as formulating rules, testing hypotheses, and gathering information (Bruner, 1961):

> Let it be clear what the act of discovery entails. It is rarely . . . that new facts are "discovered" in the sense of being encountered as Newton suggested in the form of islands of truth in an uncharted sea of ignorance. Or if they appear to be discovered in this way, it is almost always thanks to some happy hypotheses about where to navigate. Discovery, like surprise, favors the well prepared mind. . . . Discovery, whether by a schoolboy going it on his own or by a scientist cultivating the growing edge of his field, is in its essence a matter of rearranging or transforming evidence in such a way that one is enabled to go beyond the evidence so reassembled to additional new insights. (p. 22)

This quote contradicts the notion that great discoveries are not planned or predicted but rather are accidents that happen to lucky people; however, Bruner's point is supported by much historical evidence. Consider how Pasteur developed the cholera vaccine

(Root-Bernstein, 1988). Pasteur went on vacation during the summer of 1879. He had been conducting research on chicken cholera and left out germ cultures when he departed for 2 months.

> Upon his return, he found that the cultures, though still active, had become avirulent; they no longer could sicken a chicken. So he developed a new set of cultures from a natural outbreak of the disease and resumed his work. Yet he found . . . that the hens he had exposed to the weakened germ culture still failed to develop cholera. Only then did it dawn on Pasteur that he had inadvertently immunized them. (p. 26)

The process of discovery often is contrasted with scientific inquiry, which relies on the use of logic and rational examination rather than being in the right place at the right time. In fact, most discoveries are not flukes but rather a natural (albeit possibly unforeseen) consequence of systematic inquiry by the discoverer. Discoverers are not happy recipients of good fortune but rather cultivate it by expecting the unexpected. Pasteur did not leave the germ cultures unattended but rather in the care of his collaborator, Roux. When Pasteur returned from vacation, he inoculated chickens with the germs and they did not become sick.

> But when the same chickens were later injected with a more virulent strain, they died. No discovery here . . . Pasteur did not even initiate his first successful enfeeblement experiment until a few months later. . . . He and Roux had tried to enfeeble the germs by passing them from one animal to another, by growing them in different media . . . and only after many such attempts did one of the experiments succeed. . . . For some time, the strains that failed to kill chickens were also too weak to immunize them. But by March of 1880, Pasteur had developed two cultures with the properties of vaccines. The trick . . . was to use a mildly acidic medium, not a strong one, and to leave the germ culture sitting in it for a long time. Thus, he produced an attenuated organism capable of inducing an immune response in chickens. The discovery . . . was not an accident at all; Pasteur had posed a question—Is it possible to immunize an animal with a weakened infectious agent?—and then systematically searched for the answer. (Root-Bernstein, 1988, p. 29)

This scenario supports the idea that discoveries may happen by chance but the discoverer often creates those circumstances. Most discoveries are not lucky occurrences. Students require background preparation (the well-prepared mind requires declarative, procedural, and conditional knowledge). Once students possess prerequisite knowledge, careful structuring of material allows them to discover important principles.

Teaching for Discovery

As the opening scenario in Gina Brown's class illustrates, teaching for discovery requires presenting questions, problems, or puzzling situations to resolve and encouraging learners to make intuitive guesses when they are uncertain. In leading a class discussion, teachers could ask questions that have no readily available answers and tell students that their answers will not be graded. This procedure forces students to construct their understandings. Discoveries are not limited to activities within school. During a unit on ecology, students could discover why animals of a given species live in certain areas and not in others. Students might seek answers in classroom work stations, in the school media center, and on or off the school grounds. Teachers provide structure by posing questions and

giving suggestions on how to search for answers. Greater teacher structure is beneficial when students are not familiar with the discovery procedure or require extensive background knowledge. Discovery actually can impede learning when students have no prior experience with the material or background information (Tuovinen & Sweller, 1999). Classroom examples of discovery learning are given in Application 7.1.

Teaching for discovery learning may not be appropriate with well-structured content that is easily presented. Students could discover which historical events occurred in which years, but this is trivial learning. If they arrived at the wrong answers, time would be wasted in reteaching the content. Discovery seems more appropriate when the learning process is important, such as with problem-solving activities that motivate students to learn and acquire the requisite skills. However, establishing discovery situations (e.g., growing plants) often takes time, and experiments might not work. Types of discovery learning situations that occur commonly in schools are role playing, independent or group projects, and computer simulations.

As a type of minimally guided instruction, discovery learning has drawn criticism as an ineffective means of learning. Mayer (2004) reviewed research evidence from the 1950s to the 1980s that compared pure discovery learning (i.e., unguided, problem-based learning) with guided instruction. The research showed that guided instruction produced superior learning. Rather than acknowledging these research results, advocates of unguided instruction have maintained it in the limelight, often by giving it a new name (e.g., experiential,

APPLICATION 7.1

Discovery Learning

Learning becomes more meaningful when students explore their learning environments rather than listen passively to teachers. Kathy Stone uses guided discovery to help her third-grade children learn animal groups (e.g., mammals, birds, reptiles). Rather than providing students with the basic animal groups and examples for each, she asks students to provide the names of types of animals. Then she helps students classify the animals by examining their similarities and differences. Category labels are assigned once classifications are made. This approach is guided to ensure that classifications are proper, but students are active contributors as they discover the similarities and differences among animals.

A high school chemistry teacher might use "mystery" liquids and have students discover the elements in each. The students could proceed through a series of experiments designed to determine if certain substances are present in a sample. By using the experimental process, students learn about the reactions of various substances to certain chemicals and also how to determine the contents of their mystery substance.

Gina Brown uses other problem-based learning activities in her class. She often creates different classroom scenarios that describe situations involving student learning and behaviors as well as teacher actions. She divides her educational psychology students into pairs and asks them to work through each scenario and discover which learning principles best describe the situations presented.

problem-based, inquiry, or constructivist learning). Kirschner et al. (2006) contended that unguided instruction does not take into account the organization, or architecture, of cognitive structures (e.g., working memory [WM], long-term memory [LTM]); for example, such instruction tends to ignore the limits of WM and does not specify what has changed in LTM. Although there is evidence that minimally guided instruction can enhance students' problem solving and self-directed learning (Hmelo-Silver, 2004), most of the promising research has been conducted in medical or gifted education.

Notice that these criticisms pertain to minimally guided instruction. As discussed earlier in this section, guided discovery—in which teachers arrange the situation such that learners are not left to their own devices but rather receive support—can lead to effective learning. Guided discovery also makes good instructional use of the social environment, a point underscored in Chapter 6. Supports (scaffolding) for learning can be minimized when learners have developed some skills and expertise and therefore can provide their own guidance. In deciding whether to use discovery, teachers need to consider several factors including the learning objectives (e.g., acquire knowledge or learn problem-solving skills), the time available, and the cognitive capacities of students to engage effectively in discovery.

MEANINGFUL RECEPTION LEARNING

Meaningfulness and Expository Teaching

David Ausubel (1963, 1968; Ausubel & Robinson, 1969) developed a cognitive theory of *meaningful reception learning*, which is strikingly different from discovery learning. According to Ausubel (1968):

> The acquisition of subject-matter knowledge is primarily a manifestation of reception learning. That is, the principal content of what is to be learned is typically presented to the learner in more or less final form. Under these circumstances, the learner is simply required to comprehend the material and to incorporate it into his cognitive structure so that it is available for either reproduction, related learning, or problem solving at some future date. (p. 83)

Ausubel advocated using *expository teaching*, presenting information to students in an organized, meaningful fashion. The notion of expository teaching often is misunderstood:

> Few pedagogic devices in our time have been repudiated more unequivocally by educational theorists than the method of expository verbal instruction. It is fashionable in many quarters to characterize verbal learning as parrot-like recitation and rote memorization of isolated facts, and to dismiss it disdainfully as an archaic remnant of discredited educational tradition. (Ausubel, 1968, pp. 83–84)

The primary type of learning that occurs in classrooms differs fundamentally from associative and paired-associate learning. *Meaningful learning* refers to the learning of ideas, concepts, and principles by relating new information to knowledge in memory (Ausubel, 1977; Faw & Waller, 1976). Learning is meaningful when new material bears a systematic relation to relevant concepts in LTM; that is, new material expands, modifies, or elaborates information in memory. Meaningfulness also depends on personal variables such as age, background experiences, socioeconomic status, and educational background. Prior experiences determine whether students find learning meaningful.

In contrast to the inductive reasoning used in discovery learning (and as evident in the opening scenario), the Ausubel model advocates *deductive reasoning:* General ideas are taught first, followed by specific points. This model requires teachers to help students break ideas into smaller, related points and to link new ideas to similar content in memory. In cognitive information processing terms, the aims of the model are to expand propositional networks in memory by adding knowledge and to establish links between networks.

Meaningful reception learning requires much teacher–student interaction. Teachers verbally present new material, but student responses are continually solicited. Lessons must be well organized. Concepts are exemplified in diverse ways and build on one another so that students possess the requisite knowledge to benefit from the teaching.

Advance Organizers

Advance organizers, or broad statements presented at the outset of lessons, help to connect new material with prior learning. Organizers direct learners' attention to important concepts in material to be learned, highlight interrelationships among ideas presented, and link new material to what students know (Faw & Waller, 1976). Organizers also can be maps that are shown with accompanying text (Verdi & Kulhavy, 2002). It is assumed that learners' cognitive structures are hierarchically organized so that inclusive concepts subsume subordinate ones. Organizers provide information at high levels in hierarchies.

Organizers can be expository or comparative. *Expository organizers* provide students with new knowledge needed to comprehend the lesson. Expository organizers include concept definitions and generalizations. *Concept definitions* state the concept, a superordinate concept, and characteristics of the concept. In presenting the concept of warm-blooded animal, for example, a teacher might define it (i.e., animal whose internal body temperature remains relatively constant), relate it to superordinate concepts (animal kingdom), and give its characteristics (birds, mammals) (see discussion of procedural knowledge in Chapter 4). *Generalizations* are broad statements of general principles from which hypotheses or specific ideas are drawn. A generalization appropriate for the study of terrain would be: "Less vegetation grows at higher elevations." Teachers can present examples of generalizations and ask students to think of others.

Comparative organizers introduce new material by drawing analogies with familiar material. Comparative organizers activate and link networks in LTM. If a teacher were giving a unit on the body's circulatory system to students who have studied communication systems, the teacher might relate the circulatory and communication systems with relevant concepts such as the source, medium, and target. For comparative organizers to be effective, students must have a good understanding of the material used as the basis for the analogy. Learners also must perceive the analogy easily. Difficulty perceiving analogous relationships impedes learning, as we saw in the discussion of analogical reasoning in Chapter 5.

Ausubel's research showed that using organizers promoted learning over that which occurred without organizers (Ausubel, 1978); however, other studies have obtained conflicting results (Barnes & Clawson, 1975). Organizers seem most effective with lessons designed to teach how concepts are related (Mayer, 1984). If teachers stretch an analogy too far, students may not understand the connection. Organizers also are effective with difficult academic content when an analogy with familiar content is appropriate (Faw & Waller, 1976).

As with discovery learning, teachers must consider the goals of the learning. Discovery will be better for some learning outcomes, whereas the direct instructional approach of expository teaching will be preferred for others.

Another consideration is the developmental status of the learners. Organizers operate at general, abstract levels and require students to relate ideas mentally, which is beyond the capacity of young children. This deductive teaching approach works better with older students (Luiten, Ames, & Ackerson, 1980).

Evidence suggests that organizers aid transfer. Maps are effective organizers and lend themselves well to infusion in lessons via technology (Verdi & Kulhavy, 2002). Mayer (1979) reported research with college students who had no computer programming experience. Students were given programming materials to study; one group was given a conceptual model as an organizer, whereas the other group received the same materials without the model. The advance organizer group performed better on posttest items requiring transfer of learning to items different from those discussed in the instructional material. Organizers may help students relate new material to a broader set of experiences, which facilitates transfer (Application 7.2).

APPLICATION 7.2
Advance Organizers

Advance organizers help students connect new material with prior learning. Kathy Stone is teaching her students to develop comprehensive paragraphs. The students have been learning to write descriptive and interesting sentences. Mrs. Stone writes the students' sentences on the board and uses them as an organizer to show how to put sentences together to create a complete paragraph.

A middle school teacher might employ an organizer during geography. The teacher might begin a lesson on landforms (surfaces with characteristic shapes and compositions) by reviewing the definition and components of geography concepts previously discussed. The teacher wants to show that geography includes elements of the physical environment, human beings and the physical environment, and different world regions and their ability to support human beings. To do this, the teacher initially could focus on elements of the physical environment and then move to landforms. The teacher then might discuss types of landforms (e.g., plateaus, mountains, hills) by showing mock-ups and asking students to identify key features of each landform. This deductive approach gives students an overall framework or outline into which they can integrate new knowledge about the components.

In medical school an instructor teaching the effects of blood disorders might begin by reviewing the basic parts of blood (e.g., plasma, white and red cells, platelets). Then the teacher could list various categories of blood disease (e.g., anemia, bleeding and bruising, leukemia, bone marrow disease). The students can build on this outline by exploring the diseases in the different categories and by studying the symptoms and treatments for each condition.

CONDITIONS OF LEARNING

One of the best known instructional theories based on cognitive principles was formulated by Robert Gagné (1985). This theory involves the *conditions of learning,* or the circumstances that prevail when learning occurs (Ertmer, Driscoll, & Wager, 2003). Two steps are critical in applying the theory. The first is to *specify the type of learning outcome*; Gagné identified five major types (discussed later). The second is to *determine the events of learning,* or factors that make a difference in instruction. Events are internal and external: Internal events include personal dispositions and cognitive processes; external events are instructional and are deliberately planned and arranged to promote learning. These are considered in turn.

Learning Outcomes

Gagné (1984) contended that learning is complex and that learners acquire capabilities that manifest themselves in different outcomes. Outcomes are distinct when learning requires different types of cognitive information processing and when learning enables different types of performances. The five types of learning outcomes are intellectual skills, verbal information, cognitive strategies, motor skills, and attitudes (Table 7.1).

Intellectual skills include rules, procedures, and concepts. Previous chapters referred to intellectual skills as forms of procedural knowledge or production systems. This type of knowledge is employed in speaking, writing, reading, solving mathematical problems, and applying scientific principles to problems.

Verbal information, or declarative knowledge, is knowledge that something is the case. It is verbal because it is displayed verbally (in speaking or writing). Verbal information involves facts or meaningfully connected prose recalled verbatim (e.g., words to a poem or the "Star Spangled Banner"). Schemata, or organized networks of facts and events, are forms of verbal information.

Cognitive strategies are executive control processes. They include cognitive information processing skills such as attending to new information, deciding to rehearse information, elaborating, and using LTM retrieval strategies (Chapters 4 and 5). The problem-solving strategies discussed in Chapter 5 are examples of cognitive strategies.

Motor skills are developed through gradual improvements in the quality (smoothness and timing) of movements attained through practice. Whereas intellectual skills can be

Table 7.1
Learning outcomes in Gagné's theory.

Learning Outcomes	
Type	**Examples**
Intellectual skills	Rules, procedures, concepts
Verbal information	Facts, dates
Cognitive strategies	Rehearsal, problem-solving
Motor skills	Hitting a ball, juggling
Attitudes	Generosity, honesty, fairness

acquired abruptly, motor skills develop gradually with continued, deliberate practice (Ericsson et al., 1993). Intellectual skill development does not compare with the refinements in smoothness and timing found in motor-skill learning. Even practice conditions differ: Intellectual skills are practiced with different examples; motor-skill practice involves repetition of the same muscular movements.

Attitudes are internal beliefs that influence personal actions and that reflect characteristics such as generosity, honesty, and commitment to healthy living. Attitudes are inferred because they cannot be observed directly. Attitudes are learned, although unlike the preceding outcomes, they are not learned directly. Teachers can arrange proper conditions for learning intellectual skills, verbal information, cognitive strategies, and motor skills. Gagné believed that attitudes are learned indirectly through experiences and exposures to live and symbolic (televised and videotaped) models.

Learning Events

The five types of learning outcomes differ in their conditions: *Internal conditions* are prerequisite skills and cognitive processing requirements, whereas *external conditions* are environmental stimuli that support the learner's cognitive processes. One must specify as completely as possible both types of conditions when designing instruction to produce desired outcomes.

Internal conditions are learners' current capabilities, which are stored in memory as knowledge. Gagné employed an information processing framework in which instructional cues from teachers and materials activate relevant knowledge in LTM (Gagné & Glaser, 1987). Internal conditions are important for designing learning hierarchies and instruction.

External conditions differ as a function of the learning outcome and the internal conditions. To teach students a classroom rule, a teacher might inform them of the rule and write it on the chalkboard. To teach students a strategy for checking their comprehension, a teacher might demonstrate the strategy and give students practice and feedback on its effectiveness. Proficient readers are instructed differently from those with decoding problems. Each phase of instruction is subject to alteration as a function of learning outcomes and internal conditions.

Learning Hierarchies

Learning hierarchies are organized sets of intellectual skills. The highest element in a hierarchy is the *target skill.* To devise a hierarchy, one begins at the top and asks what skills the learner must perform prior to learning the target skill or what skills are immediate prerequisites for the target skill. Then one asks the same question for each prerequisite skill, continuing down the hierarchy until one arrives at the skills the learner can perform now (Dick & Carey, 1985; Merrill, 1987). Figure 7.1 portrays a sample learning hierarchy.

Hierarchies are not linear orderings of skills. One often must apply two or more prerequisite skills to learn a higher-order skill, with neither of the prerequisites dependent on the other. Nor are higher-order skills necessarily more difficult to learn than lower-order ones. Some prerequisites may be difficult to acquire; once learners have mastered the lower-order skills, learning a higher-order one may seem easier.

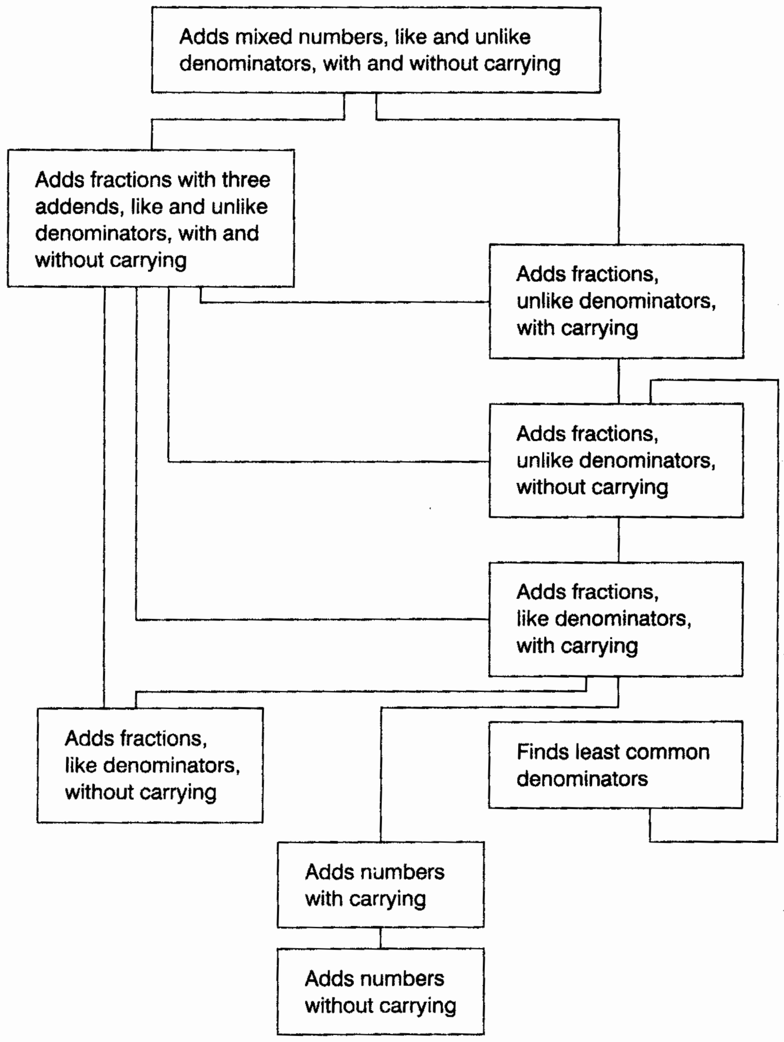

Figure 7.1
Sample learning hierarchy.

Phases of Learning

Instruction is a set of external events designed to facilitate internal learning processes. Table 7.2 shows the nine phases of learning grouped into the three categories (Gagné, 1985).

Preparation for learning includes introductory learning activities. During *attending*, learners focus on stimuli relevant to material to be learned (audiovisuals, written materials, or teacher-modeled behaviors). The learner's *expectancy* orients the learner to the goal (learn a motor skill or learn to reduce fractions). During retrieval of relevant information from LTM, learners activate the portions relevant to the topic studied (Gagné & Dick, 1983).

The main phases of learning are *acquisition* and *performance*. *Selective perception* means that the sensory registers recognize relevant stimulus features and transfer them to

Table 7.2
Gagné's phases of learning.

Category	Phase
Preparation for learning	Attending
	Expectancy
	Retrieval
Acquisition & performance	Selective perception
	Semantic encoding
	Retrieval and responding
	Reinforcement
Transfer of learning	Cueing retrieval
	Generalizability

WM for processing. *Semantic encoding* is the process whereby new knowledge is transferred to LTM. During *retrieval and responding,* learners retrieve new information from memory and make a response demonstrating learning. *Reinforcement* refers to feedback that confirms the accuracy of a student's response and provides corrective information as necessary.

Transfer of learning phases include cueing retrieval and generalizability. In *cueing retrieval,* learners receive cues signaling that previous knowledge is applicable in that situation. When solving word problems, for instance, a mathematics teacher might inform learners that their knowledge of right triangles is applicable. *Generalizability* is enhanced by providing learners the opportunity to practice skills with different content and under different circumstances (e.g., homework, spaced review sessions).

These nine phases are equally applicable for the five types of learning outcomes. Gagné and Briggs (1979) specified types of instructional events that might accompany each phase (Table 7.3). Instructional events enhancing each phase depend on the type of outcome. Instruction proceeds differently for intellectual skills than for verbal information.

Gagné's theory incorporates each of the five elements mentioned at the beginning of this chapter:

- Learning occurs in phases (Table 7.2).
- Skills to be learned are acquired sequentially as set forth in the hierarchy; these are broken down into small steps.
- Practice, feedback, and review are integral components of the system.
- Social modeling is employed during the instructional phases (3–6).
- Motivation is a function of learner's attitudes, and the external conditions of learning include contextual factors.

Furthermore, the theory represents a systematic combination of principles of learning and instruction. It highlights many of the ideas discussed in this text, including the structure and representation of knowledge, retrieval, practice, feedback, transfer, and motivation.

One issue in applying Gagné's theory is that developing learning hierarchies can be difficult and time consuming. The process requires expertise in the content domain to

Table 7.3
Instructional events accompanying learning phases (Gagné).

Phase	Instructional Event
Attending	Inform class that it is time to begin.
Expectancy	Inform class of lesson objective and type and quantity of performance to be expected.
Retrieval	Ask class to recall subordinate concepts and rules.
Selective perception	Present examples of new concept or rule.
Semantic encoding	Provide cues for how to remember information.
Retrieval and responding	Ask students to apply concept or rule to new examples.
Reinforcement	Confirm accuracy of students' learning.
Cueing retrieval	*Give short quiz on new material.*
Generalizability	*Provide special reviews.*

determine the successive prerequisite skills—the scope and sequence of instruction. Even a seemingly simple skill may have a complex hierarchy if learners must master several prerequisites. For those skills with less well-defined structures (e.g., creative writing), developing a hierarchy may be difficult. Another issue is that the system allows for little learner control because it prescribes how learners should proceed. The current educational emphasis on constructivism seems to be at odds with the basic assumptions of the theory, although one might argue that even under prescriptive learning conditions students still construct their knowledge.

Gagné's theory has made significant contributions to the study of learning and instruction (Ertmer et al., 2003). The theory provides a solid standard against which to gauge how well instructional theories incorporate principles of learning. We now turn to other instructional models that are less elaborate but also incorporate learning principles and specify instructional conditions to optimize learning, retention, and transfer.

MODELS OF INSTRUCTION

Over the years, a large number of instructional models have been formulated. These vary in precision, theoretical orientation, and critical components. No attempt is made here to cover instructional models extensively, because that extends beyond the scope of this text. Rather, this section covers a small subset chosen to show how instructional principles link to learning.

Learning Time

Carroll (1963, 1965) formulated a model of school learning that places primary emphasis on the instructional variable of time spent on learning. Carroll assumed that learning tasks

can be specified clearly and that reliable means exist for determining whether students have learned the tasks.

The central premise is that students successfully learn to the extent that they spend the amount of time they need to learn. *Time* means academically engaged time, or time spent paying attention and trying to learn. This is a cognitive definition because it goes beyond a simple behavioral indicator of clock time. Within this framework, Carroll postulated factors that influence how much time learning requires and how much time is actually spent learning.

Time Needed for Learning. One influence on this factor is *aptitude for learning the task.* Learning aptitude depends on the amount of prior task-relevant learning and on personal characteristics such as abilities and attitudes. A second, related factor is *ability to understand instruction.* This variable interacts with instructional method; for example, some learners comprehend verbal instruction well, whereas others benefit more from visual presentations.

Quality of instruction refers to how well the task is organized and presented to learners. Quality includes what learners are told about what they will learn and how they will learn it, the extent to which they have adequate contact with the learning materials, and how much prerequisite knowledge is acquired prior to learning the task. The lower the quality of instruction, the more time learners require to learn.

Time Spent in Learning. *Time allowed for learning* is one influence on this factor. The school curriculum includes so much content that time allotted for a particular type of learning is less than optimal for some students. When teachers present material to the entire class at once, some learners are more likely to experience difficulty grasping it and require additional instruction. When students are ability grouped, the amount of time devoted to different content varies depending on the ease with which students learn.

A second influence is *time the learner is willing to spend learning.* Even when learners are given ample time to learn, they may not spend that time working productively. Whether due to low interest, high perceived task difficulty, or other factors, students may not be motivated to persist at a task for the amount of time they require to learn it. Carroll incorporated these factors into a formula to estimate the degree of learning for any student on a given task:

$$\text{degree of learning} = \text{time spent}/\text{time needed}$$

Ideally, students spend as much time as they need to learn (degree of learning $= 1.0$), but learners typically spend either more time (degree of learning > 1.0) or less time (degree of learning < 1.0) than they require.

Carroll's model highlights the importance of academic engaged time required for learning and the factors influencing time spent and time needed to learn. It does not offer specific prescriptions for how to correct inadequate student learning. The model incorporates valid psychological principles, but only at a general level as instructional or motivational factors. It does not explore cognitive engagement in depth. Carroll (1989) admitted that more research was needed to complete the details. As discussed in the next section,

mastery learning researchers, who have systematically investigated the time variable, have provided greater specificity.

Over the years, a number of publications have decried the way that time is misspent in education (Zepeda & Mayers, 2006). The time variable is central to current discussions on ways to maximize student achievement. For example, the Federal government's No Child Left Behind Act of 2001 greatly expanded its role in elementary and secondary education (Shaul & Ganson, 2005). Although the act did not specify how much time was to be devoted to instruction, its requirements for student achievement and its accountability standards, combined with various writers calling for better use of time, have led school systems to reexamine their use of time to ensure better student learning.

One consequence is that many secondary schools have abandoned the traditional 6-hr schedule in favor of *block scheduling.* Although there are variations, many use the A/B block, in which classes meet on alternate days for longer periods per day. Presumably, block scheduling allows teachers and students to explore content in greater depth, which often was not possible with the traditional shorter class periods (e.g., 50 min).

Given that block scheduling still is relatively new, there is not a lot of research assessing its effectiveness. Zepeda and Mayers (2006) reviewed the extant literature. These authors found that block scheduling may improve school climate and students' grade-point averages, but studies showed inconsistent results for student attendance and scores on standardized tests. As block scheduling becomes more common, we can expect more research that may clarify these inconsistencies.

Another means for increasing time for learning is through out-of-school programs such as after-school programs and summer school. Compared with research on block scheduling, research on the effects of out-of-school programs shows greater consistency. In their review of the literature, Lauer et al. (2006) found positive effects for such programs on students' reading and mathematics achievement; effects were larger for programs with enhancements (e.g., tutoring). Mahoney, Lord, and Carryl (2005) found benefits of after-school programs on children's academic performances and motivation; results were strongest for children rated as highly engaged in the after-school program's activities. Consistent with Carroll's model, we might conclude that out-of-school programs are successful to the extent that they focus on student learning and provide supports to encourage it.

Mastery Learning

Carroll's model predicts that if students vary in aptitude for learning a subject and if all receive the same amount and type of instruction, their achievement will differ. If the amount and type of instruction vary depending on individual differences among learners, then each student has the potential to demonstrate mastery; the positive relation between aptitude and achievement will disappear because all students will demonstrate equal achievement regardless of aptitudes.

These ideas form the basis of *mastery learning* (Anderson, 2003; Bloom, 1976; Bloom, Hastings, & Madaus, 1971). Mastery learning incorporates Carroll's ideas into a systematic instructional plan that includes defining mastery, planning for mastery, teaching for mastery, and grading for mastery (Block & Burns, 1977). Mastery learning contains cognitive elements, although its formulation seems quite basic compared with many current cognitive theories.

To define *mastery*, teachers prepare a set of objectives and a final (summative) exam. Level of mastery is established (e.g., where *A* students typically perform under traditional instruction). Teachers break the course into learning units mapped against course objectives.

Planning for mastery means teachers plan instructional procedures for themselves and students to include corrective feedback procedures (formative evaluation). Such evaluation typically takes the form of unit mastery tests that set mastery at a given level (e.g., 90%). Corrective instruction, which is used with students who fail to master aspects of the unit's objectives, is given in small-group study sessions, individual tutorials, and supplemental materials.

At the outset of *teaching for mastery*, teachers orient students to the mastery procedures and provide instruction using the entire class, small groups, or individual seatwork activities. Teachers give the formative test and certify which students achieve mastery. Students who fall short might work in small groups reviewing troublesome material, often with the aid of peer tutors who have mastered the material. Teachers allow students time to work on remedial materials along with homework.

Grading for mastery includes a summative (end-of-course) test. Students who score at or above the course mastery performance level receive *A* grades; lower scores are graded accordingly. Mastery learning has been most frequently applied at the elementary and secondary school levels, although colleges and universities have widely used Keller's Personalized System of Instruction (PSI) (Chapter 2). Callahan and Smith (1990) found that PSI worked effectively with junior high gifted students.

The emphasis on student abilities as determinants of learning may seem uninteresting, given that abilities generally do not change much as a result of instructional interventions. Bloom (1976) also stressed the *alterable variables* of schooling: cognitive entry behaviors (e.g., student skills and cognitive processing strategies at the outset of instruction), affective characteristics (e.g., interest, motivation), and specific factors influencing the quality of instruction (e.g., student participation, type of corrective feedback). Instructional interventions can improve these variables.

Reviews of the effect of mastery learning on student achievement are mixed. Block and Burns (1977) generally found mastery learning more effective than traditional forms of instruction. With college students, Péladeau, Forget, and Gagné (2003) obtained results showing that mastery learning improved students' achievement, long-term retention, and attitudes toward the course and subject matter. Kulik et al. (1990) examined more than 100 evaluations of mastery learning programs and found positive effects on academic performances and course attitudes among college, high-school, and upper-grade elementary school learners. They also found that mastery learning may increase the time students spend on instructional tasks. In contrast, Bangert et al. (1983) found weaker support for mastery learning programs. They noted that mastery-based instruction was more effective at the college level than at lower levels. Its effectiveness undoubtedly depends on the proper instructional conditions (e.g., planning, teaching, grading) being established (Kulik et al., 1990).

Students participating in mastery instruction often spend more time in learning compared with learners in traditional classes (Block & Burns, 1977). Given that time is at a premium in schools, much mastery work—especially remedial efforts—must be accomplished outside of regular school hours. Most studies show smaller effects of mastery instruction on affective outcomes (e.g., interest in and attitudes toward the subject matter) than on academic outcomes.

An important premise of mastery learning is that individual differences in student learning decrease over time. Anderson (1976) found that when remedial students gained experience with mastery instruction, they gradually required less extra time to attain mastery because their entry-level skills improved. These results imply cumulative benefits of mastery learning. There remains, however, the question of how much practice is enough (Péladeau et al., 2003). Too much repetitive practice might negatively affect motivation, which will not promote learning. These points require further research but have important instructional implications. Some examples of mastery learning are given in Application 7.3.

Inquiry Teaching

Unlike expository teaching that is direct in its instructional approach, inquiry teaching is a minimally guided method. We saw a type of inquiry learning in the opening scenario. Inquiry methods often are referred to by other names such as problem-based, experiential, and constructivist learning. Inquiry is a form of discovery learning, although it can be structured to have greater teacher direction.

Several years ago, Collins (1977; Collins & Stevens, 1983) formulated a theory of instruction based on the Socratic teaching method. The goals are to have students reason,

APPLICATION 7.3
Mastery Learning

A mastery learning approach can be very beneficial in certain learning environments. For example, in a remedial reading group for secondary students, a well-organized mastery learning program would allow students to progress at their own rates. Students motivated to make rapid progress are not slowed down by this type of instruction, as might happen if they are placed in a traditional learning format. Whether teachers use existing mastery learning reading programs or develop their own, the key is to include a progression of activities from less difficult to more difficult. The program should have checkpoints at which the students interact with the teacher so that their progress is evaluated with reteaching or special assistance provided if needed.

Young children entering school for the first time come with a wide range of experiences and abilities. Mastery learning can help teachers deal more effectively with the varying abilities and developmental levels. Mastery learning techniques can be implemented by using learning centers and small groups. Children can be placed in the different centers and groups according to their current levels. Then they can move through various developmental levels according to their own readiness rates.

The mastery approach also can build students' self-efficacy for learning. As they note their progress in completing units, they are apt to believe they are capable of further learning. Enhancing self-efficacy is particularly important with remedial learners who have encountered school failures and doubt their capabilities to learn, as well as for young children who enter school with limited experiences and skills.

derive general principles, and apply them to new situations. Appropriate learning outcomes include formulating and testing hypotheses, differentiating necessary from sufficient conditions, making predictions, and determining when making predictions requires more information.

In implementing the model, the teacher repeatedly questions the student. Questions are guided by rules such as "Ask about a known case," "Pick a counterexample for an insufficient factor," "Pose a misleading question," and "Question a prediction made without enough information" (Collins, 1977). Rule-generated questions help students formulate general principles and apply them to specific problems.

The following is a sample dialogue between teacher (T) and student (S) on the topic of population density (Collins, 1977):

T: In Northern Africa is there a large population density?

S: In Northern Africa? I think there is.

T: Well there is in the Nile valley, but elsewhere there is not. Do you have any idea why not?

S: Because it's not good for cultivating purposes?

T: It's not good for agriculture?

S: Yeah.

T: And do you know why?

S: Why?

T: Why is the farming at a disadvantage?

S: Because it's dry.

T: Right. (p. 353)

Although this instructional approach was designed for one-to-one tutoring, with some modifications it seems appropriate with small groups of students. One issue is that persons who serve as tutors require extensive training to pose appropriate questions in response to a student's level of thinking. Also, good content-area knowledge is a prerequisite for problem-solving skills. Students who lack a decent understanding of basic knowledge are not likely to function well under an inquiry system designed to teach reasoning and application of principles. Other student characteristics (e.g., age, abilities) also may predict success under this model. As noted earlier in this chapter, in deciding whether to use an inquiry-based approach, teachers must consider the student outcomes and the likelihood that students can successfully engage in the inquiry process.

Instruction with Worked Examples

An instructional focus of many cognitive researchers is the role of worked examples. *Worked examples* typically present problem solutions in step-by-step fashion and often include accompanying diagrams. They portray an expert's problem-solving model for learners to study before they begin to emulate it. A worked example is shown in Figure 7.2 (Glover, Ronning, & Bruning, 1990).

Problem Statement: Find the Square Root of 7,225

Steps		*Algorithm*	
1.		$\sqrt{7225}$	
2.		$\sqrt{72.25}$	Mark off in units of two from the decimal point.
3.	8 x 8	8 $\sqrt{72.25}$ 64 825	Find the largest perfect square in the two numbers to the left of the decimal. Subtract from 72 and "bring down" the next two numbers.
4.	160	8 $\sqrt{72.25}$ 64 825	Double the 8 and add a zero. Use the number (160) as a trial divisor: 825 divided by 160 = 5, plus a remainder.
5.	165 x 5	8 5 $\sqrt{72.25}$ 64 825 825	Substitute the 5 for the zero and multiply (165 x 5). Product equals 825. Solution achieved.

Figure 7.2
Sample worked example.
Source: Cognitive Psychology for Teachers by Glover, © Reprinted by permission of Pearson Education, Inc., Upper Saddle River, NJ.

There is, of course, nothing new about using worked examples in teaching. Researchers of various theoretical bents advocate using modeled exemplars. Previously (Chapter 3), we considered the benefits of cognitive modeling and demonstration plus explanation (Rosenthal & Zimmerman, 1978; Schunk, 1981). From a motivational perspective, worked examples may help instill self-efficacy in learners for succeeding when they believe they understand the model and can apply the strategy themselves (Schunk, 1991). Worked examples also figure prominently in theories of concept acquisition (Bruner et al., 1956).

What is new is the link of worked examples to cognitive learning principles, especially for complex forms of learning, such as algebra, physics, and geometry (Atkinson et al., 2000, 2003). Applying the novice–expert model (Chapter 10), researchers have found that experts typically focus on deeper (structural) aspects of problems and that novices more often deal with surface features. Practice alone is less effective in promoting skills than is practice coupled with worked examples (Atkinson et al., 2000).

Worked examples seem most beneficial with students in the early stages of skill acquisition, as opposed to proficient learners who are refining skills. Its applicability is seen clearly in the four-stage model of skill acquisition within the ACT-R framework (Anderson, Fincham, & Douglass, 1997; see Chapter 4). In stage 1, learners use analogies to relate examples to problems to be solved. In stage 2, they develop abstract declarative rules through practice. During stage 3, performance becomes quicker and smoother as aspects

of problem solution become automatized. By stage 4, learners have in memory many types of problems and can retrieve the appropriate solution strategy quickly when confronted with a problem. Use of worked examples is best suited for stage 1 and early stage 2 learners. During later stages, people benefit from practice to hone their strategies, although even at advanced stages studying solutions of experts can be helpful.

From an instructional perspective, certain issues are critical. One is how to integrate the components of an example, such as diagram, text, aural information, and subgoals. It is imperative that a worked example not overload the learner's WM, which multiple sources of information presented simultaneously can do. Research supports the prediction that dual presentation facilitates learning better than single-mode presentation (Atkinson et al., 2000; Mayer, 1997; see the technology section later in this chapter). This result is consistent with dual-coding theory (Paivio, 1986; see Chapter 4), with the caveat that too much complexity is not desirable. Similarly, examples intermixed with subgoals help create deep structures and facilitate learning.

A key point is that examples that include multiple presentation modes should be unified so that learners' attention is not split across nonintegrated sources. Aural and verbal explanations should indicate to which aspect of the example they refer, so learners do not have to search on their own. Subgoals should be clearly labeled and visually isolated in the overall display.

A second issue concerns how examples should be sequenced during an instructional unit. Research supports the conclusions that two examples are superior to a single one, that varied examples are better than two of the same type, and that intermixing examples and practice is more effective than a lesson that presents examples followed by practice problems (Atkinson et al., 2000). Gradually fading out worked examples in an instructional sequence is associated with better student transfer of learning (Atkinson et al., 2003).

Chi, Bassok, Lewis, Reimann, and Glaser (1989) found that students who provide *self-explanations* while studying examples subsequently achieve at higher levels compared with students who do not self-explain. Presumably, the self-explanations help students understand the deep structure of the problems and thereby encode it more meaningfully. Self-explanation also is a type of rehearsal, and the benefit of rehearsal on learning is well established. The implication for instruction is to encourage students to self-explain while studying worked examples, for example, by verbalizing subgoals.

In summary, there are several features that when incorporated with worked examples help learners create cognitive schemas to facilitate subsequent achievement (Table 7.4). These instructional strategies are best employed during the early stages of skill learning. Through practice, these initial cognitive representations should evolve into the refined schemas that experts employ.

The worked examples literature lends itself to integration with findings from other research traditions. For example, verbalization is a key part of self-instructional training (Chapter 3). From a social cognitive perspective, verbalization can help build self-efficacy and motivation as learners become aware that they understand a strategy for solving problems. Atkinson et al. (2000) discuss the need to provide incentives for students to self-explain. The modeling literature (Chapter 3) suggests that peer models who demonstrate solution strategies and verbalize cognitive explanations can be especially effective

Table 7.4
Suggestions for using worked examples in instruction.

- Present examples in close proximity to problems students will solve.
- Present multiple examples showing different types of problems.
- Present information in different modalities (aural, visual).
- Indicate subgoals in examples.
- Ensure that examples present all information needed to solve problems.
- Teach students to self-explain examples and encourage self-explanations.
- Allow sufficient practice on problem types so students refine skills.

teachers and raise observers' self-efficacy. Students who provide self-explanations are serving to construct their understandings of the content. In summary, although this material on worked examples is based on Anderson's ACT-R theory and reflects an information processing approach to skill learning (Lee & Anderson, 2001), its principles align well with other cognitive, constructivist, and motivational theories discussed in this text.

Cognitive Load

Recall from our discussions on cognitive information processing (Chapters 4 and 5) that the human information processing system only can handle so much processing at once. For example, if too many stimuli impinge simultaneously, observers will miss many of them because of their limited attentional capacity. The storage capacity of WM is limited. Because information processing takes time and involves multiple cognitive processes, at any given time only a limited amount of information can be held in WM, transferred to LTM, rehearsed, and so forth.

Cognitive load theory takes these information processing limitations into account in the design of instruction (Sweller, van Merriënboer, & Pass, 1998). *Cognitive* load, or the demands on the information processing system, can be of two types: *intrinsic cognitive load* and *extrinsic cognitive load. Intrinsic cognitive load* depends on the unalterable properties of the information to be learned and is eased only when learners acquire an effective cognitive schema to deal with the information. *Extrinsic cognitive load* is caused by the manner in which the material is presented or the activities required of the learner (Bruning et al., 2004). For example, in learning key trigonometric relationships (e.g., sine, tangent), a certain cognitive load (intrinsic) is inherent in the material to be learned, namely, developing knowledge about the ratios of sides of a right triangle. How the material is taught influences the extrinsic cognitive load. Teachers who give clear presentations help minimize extrinsic cognitive load, whereas those who explain these concepts poorly increase extrinsic load.

Mayer and Moreno (2003) explained this slightly differently by distinguishing three types of cognitive demands during learning. *Essential processing* refers to cognitive processes necessary to understand the material (similar to intrinsic load). *Incidental processing* refers to processing not necessary for learning but which may help increase understanding. *Representational holding* denotes temporarily holding information in

memory while other information is being processed. Mayer and Moreno suggested that learning proceeds best when learners focus their resources on essential processing and little or no resources on the other two types.

A key idea of cognitive load theory is that instructional methods decrease extraneous cognitive load so that existing resources are devoted to learning (van Merriënboer & Sweller, 2005). The use of scaffolding should be beneficial (van Merriënboer, Kirschner, & Kester, 2003). Initially, the scaffold helps learners acquire skills that they would be unlikely to acquire without the assistance. The scaffolding helps minimize the extrinsic load, so learners can focus their resources on the intrinsic demands of the learning. As learners develop a schema to work with the information, the scaffold assistance can be phased out.

Another suggestion is to use simple-to-complex sequencing of material (van Merriënboer et al., 2003). Several of the instructional approaches covered in this chapter recommend such a sequence (e.g., Gagné's). Complex learning is broken down into simple parts that are acquired and combined into a more complex sequence. This procedure minimizes cognitive load at any given time, so that learners can fully focus their cognitive resources on the learning at hand.

A third suggestion is to use authentic tasks in instruction. Reigeluth's (1999) *elaboration theory*, for example, requires identifying conditions that simplify performance of the task and then begin instruction with a simple but authentic case (e.g., one that might be encountered in the real world). Tasks that have real-world significance help minimize extrinsic load because they do not require learners to engage in extraneous processing to understand the context. It is more meaningful, for example, for students to determine the sine of the angle formed by joining a point 40 ft from the school's flagpole to the top of the pole than it is to solve comparable trigonometric problems in a textbook.

Cognitive load calls attention to the processing demands required of students for them to learn. It suggests that content be examined to determine the difficulty of its intrinsic load and that teaching methods be geared to not place excessive extrinsic load on learners. Its basic ideas are compatible with many of the cognitive and constructivist principles of teaching and learning addressed in this text.

Peer-Assisted Learning

Several instructional models utilize *peer-assisted learning*, defined as instructional approaches in which peers serve as active agents in the learning process (Rohrbeck et al., 2003). Models emphasizing peer-assisted learning include peer tutoring, reciprocal teaching, and collaborative learning (Palincsar & Brown, 1984; Slavin, 1995; Strain et al., 1981; see Chapters 2, 3, 5, and 6).

Peer-assisted learning has received increased attention in recent years because it links firmly with constructivism, especially those models that stress social interaction. Vygotsky's theory (1978, 1987; see Chapter 6) emphasizes the role of the social environment—including peers—in the construction of understanding. In addition to the learning benefits, peer-assisted learning also can foster academic and social motivation for learning (Rohrbeck et al., 2003). Peers who stress academic learning convey its importance, which then can motivate others in the social environment.

Peer-assisted learning has been shown to promote achievement. In their review of the literature, Rohrbeck et al. (2003) found that peer-assisted learning was most effective with

younger (first through third graders), urban, low-income, and minority children. These are promising results, given the risk to academic achievement associated with urban, low-income, and minority students. Rohrbeck et al. (2003) did not find significant differences due to content area (e.g., reading, mathematics).

As with other instructional models, teachers need to consider the desired learning outcomes in determining whether peer-assisted learning should be used. Some types of lessons (e.g., those emphasizing inquiry skills) would seem to be ideally suited for this approach, especially if the development of social outcomes also is an objective.

RESEARCH ON TEACHING

Years ago, teaching was viewed in the narrow sense of teacher activities that led to student learning; specifically, presenting instruction and having students practice applying skills. Learning was unidirectional: Teachers influenced students. An important part of the teacher's job was to arrange the environment properly so students could respond and be reinforced. Much learning could occur even with little teacher–student interaction (Keller, 1968). This is a behavioral view of learning because it does not address cognitive and constructivist processes.

This picture of teaching has changed dramatically. Today we know that practically everything teachers do affects student learning, that learning is a complex process, and that learning involves reciprocal interactions among teachers and instructional activities, learners' cognitive processes and constructions, and facets of the instructional environment (Oser & Baeriswyl, 2001; Pintrich & Schunk, 2002). Compared with earlier behaviorally oriented research, current investigations examine cognitive and constructivist teaching factors in depth. This section covers two aspects of teaching that have been extensively researched and that have important effects on student learning: (a) planning and decision making and (b) instructional practices.

Teacher Planning and Decision Making

Planning Models. Planning and decision making are critical to teaching and student learning. Early models of planning were highly prescriptive because they specified clearly what teachers should do to promote student learning (Clark & Yinger, 1979). These models included steps such as specifying learning objectives, selecting teacher and student activities, organizing instruction, and determining methods of evaluation.

In contrast to these linear models, a different type of model views planning as beginning with teacher decisions about what types of activities to use. Within this context, objectives arise and are integrated with activities. The means and ends of teaching become integrated, which means that goals are not completely specified initially.

Recent research has placed greater emphasis on exploring teachers' thought processes before, during, and after teaching to examine teacher planning at different times (Clark & Peterson, 1986). Planning is not confined to what teachers do prior to instruction; rather, it is a continuous process. This view reflects a cognitive information processing approach, which stresses the receiving, organizing, and encoding of information in memory (Gagné et al., 1993).

Research using a variety of methods including teacher verbal reports and think-alouds shows that teacher planning strongly reflects student characteristics such as needs, abilities, and motivational variables (Clark & Peterson, 1986). Teachers are concerned with how to foster attainment of learning objectives given their students' abilities and with how their students will receive instruction and activities. When teachers take interest value into account, student activities often do not follow logically from specification of objectives and the latter is not always important in planning.

Motivational concerns are important in teachers' decisions about planning. Clark and Yinger (1979) asked teachers to view videotaped segments of their teaching and recall what they were thinking about at the time. Teachers considered using alternative teaching strategies only when instruction was not functioning well. The main cue to assess instructional effectiveness was students' involvement and participation, which are motivational variables. Teachers considered changing approaches when they noticed that student motivation was lagging.

Teachers often do not follow a linear planning model because they do not plan lessons strictly in line with stated objectives. They often begin by considering the setting and content and then think about motivational concerns (e.g., student involvement and participation). When they deviate from their plans during teaching, they often do so because of motivational problems. Teachers and students influence one another. Teachers affect student motivation and learning through planning, but student reactions to instruction cause teachers to rethink their approach and implement what they believe are better strategies for learning.

Research also has examined differences in planning between expert and novice teachers (Hogan, Rabinowitz, & Craven, 2003). During lesson planning, novices tend to consider the class as a whole, whereas experts focus on individual students. Experts tend to plan multiple ways to teach the content, which helps to ensure that it can be learned by all students. In contrast, novices focus on planning a lesson in a certain fashion and build in fewer adaptations. Novices address short-term planning for the attainment of immediate goals, whereas experts also fit short-term lesson plans into long-term curriculum plans. Experts engage in curriculum planning at various levels—yearly, unit, and daily. Interestingly, experts do somewhat less written planning, tending to keep large aspects as unwritten cognitions; novices use more written lessons including scripting introductions and parts of lessons.

Instructional Grouping. Another critical aspect of planning is *grouping for instruction.* Three types of grouping structures are competitive, cooperative, and individualistic (Ames, 1984; Johnson & Johnson, 1974; Slavin, 1983). *Competitive structures* negatively link individuals' goals so that if Liz attains her goal, then the chances of others attaining their goals are lowered. In *cooperative structures,* by contrast, individuals' goals are positively linked such that Liz can attain her goal only if others attain theirs. *Individualistic structures* have no link between individuals' goals.

Structures can affect learning and motivation in many ways. They help to provide cues about students' capabilities (Ames, 1984). Competitive structures highlight the importance of ability and promote social comparisons with others. Motivation and learning improve when students believe they are performing better than others but may decline if they perceive their work as poorer. In competitive situations, a few students regularly receive most of the rewards, which is not motivating for all students.

In individualistic structures, students compare their present work with previous efforts to determine progress (Ames, 1984). The perception of self-improvement substantiates self-efficacy for learning and enhances motivation and learning (Schunk, 1989).

In cooperative structures, students share in successes of the group. Ames (1981) compared the effects of competitive and cooperative structures on children's self-evaluations. In cooperative groups, the outcome affected students' perceptions of their abilities and feelings of satisfaction. Group success alleviated negative self-perceptions resulting from poor individual performance, and group failure lowered positive self-perceptions of students who performed well. Failure in competitive situations has a stronger effect on self-perceptions than does failure in noncompetitive situations. In cooperative groups, low achievers share in the group success as much as high achievers. At the same time, when cooperative groups fail, dissatisfaction can be high regardless of individual performance. For low achievers, successful cooperative groups can build self-confidence; unsuccessful ones, however, can have the same type of negative effect on self-efficacy as failure under competitive conditions (Ames & Felker, 1979).

Whether teachers should use competitive, cooperative, or individualistic structures for particular activities depends on several factors, including the purpose of instruction, ease of grouping, type of activity, potential effects of success and failure under different arrangements, and amount of social cohesiveness that exists. Regardless of structure, planning activities at which students can succeed with diligent effort to enhance their self-perceptions, motivation, and learning is important.

Instructional Practices

Effective Teaching. Shulman (1986) described an organizational framework for comparing expert–novice differences in teaching. In this model, teachers develop competency in three areas: content knowledge (understanding the concepts in the domain being taught), pedagogical content knowledge (ability to convey one's knowledge of the content through multiple teaching modes), and pedagogical knowledge (classroom guidance skills including management and communication). Expertise develops across all areas. In the area of pedagogical content knowledge, researchers have shown that experts spend less time shifting activities, present concepts and ideas in a shorter time, and use questions and discussions more effectively to determine student understanding. Experts also use more demonstrations and multiple modes of presentation. As teachers develop expertise, the class environment shifts from teacher centered to student centered (Hogan et al., 2003).

Much research has investigated how teaching practices affect student achievement. In several large-scale studies, some teachers were trained to implement specific instructional procedures, whereas others taught in their regular manner. These studies generally showed that trained teachers produce higher achievement (Brophy & Good, 1986). Rosenshine and Stevens (1986) summarized how successful instructors teach well-structured material (Table 7.5).

These suggestions link well with cognitive and constructivist learning principles (Anderson, 1990; Gagné et al., 1993; Winne, 2001). Given that WM is limited in capacity, teachers should not present too much new information at once or require unduly complex cognitive processing by students. One means of assisting students to integrate new information into LTM networks is to cue relevant prior information from memory by

Table 7.5
Principles for teaching structured content.

- Begin lesson with brief review of prior prerequisite learning.
- Provide short statement of objectives.
- Present material in short steps with student practice after each step.
- Give clear explanations and demonstrations.
- Provide for much student practice of new learning.
- Ask questions and check for understanding by all students.
- Monitor students during guided practice.
- Provide feedback and corrective instruction as necessary.
- Give clear directions for seatwork; monitor as necessary.

reviewing it during a lesson overview. When skills are well established, many aspects of skilled performance occur automatically (e.g., decoding in good readers). Student practice facilitates automaticity so that eventually executing mental processes requires little effort (Rosenshine & Stevens, 1986). Practice is a form of rehearsal that also helps to organize and store information in memory. Automatic processing helps clear space in WM for new material. Clear explanations and demonstrations ensure that students understand the content and facilitate their mental constructions of knowledge. Asking students questions, checking for understanding, monitoring their work, and providing corrective feedback ensure proper learning and allow for correction of errors before faulty learning becomes established.

Presenting material in small steps is helpful for children because of developmental limitations in information processing capability, for students with learning problems who may have difficulty processing information and can become easily overloaded, and for students of any age during the early stages of learning. Younger students need more practice and feedback; with development, the amount of presentation time can increase relative to practice because older students rehearse and encode information better (Pintrich & Schunk, 2002). Organizing information hierarchically so that memory networks can be developed through teaching is desirable.

By integrating learning research with research on teaching, one can say that teaching practices facilitate learning if they:

- break material to be learned into small steps;
- give learners practice on each step before introducing complexity;
- assist encoding by relating new information to prior knowledge;
- give additional practice to facilitate automatic processing.

This instructional approach works best with well-structured content taught step by step (e.g., factual knowledge, mathematical algorithms, mechanics of writing letters, English grammar). The approach is not as applicable with less-structured content (e.g., composition writing, discussions of social issues) or with learning goals that stress students' constructions of understanding. In applying this approach, one must consider student developmental level and other potential limiting factors.

Teaching Functions. Rosenshine and Stevens (1986) developed the following list of six teaching functions based on cognitive information processing research and research on teaching:

1. review and check previous day's work; reteach if necessary;
2. present new material;
3. give students guided practice; check for understanding;
4. offer feedback; reteach if necessary;
5. give students independent practice;
6. review at spaced intervals (weekly, monthly).

These steps typically are part of directed instructional models (Hunter, 1982). One research challenge is to explore links between teaching practices and learning principles, especially those involving learners' cognitive processes (Winne, 2001). For example, during the lesson focus phase, teachers cue knowledge and relate it to the lesson purpose. Learning research suggests that cued information is activated in students' memories and that links are formed with the lesson content.

Another area for research is to determine ways to implement effective instructional models. Independent practice, for example, can occur when students work alone or in small groups. Research on cooperative learning shows that small groups operate best when each group member is responsible for some aspect of the task (Slavin, 1983). Research might determine how to subdivide tasks during independent practice to facilitate learning and self-efficacy among group members.

LEARNER CHARACTERISTICS

Theories and models of instruction consider characteristics of learners and teachers that affect instruction and student learning. This section examines some of these qualities, including learner aptitudes, cognitive styles, and information processing capabilities. The section concludes with suggestions for adapting instruction to individual student differences.

Aptitude–Treatment Interactions

ATIs reflect the principle of tailoring instruction to important student characteristics (Snow, Corno, & Jackson, 1996). *Aptitudes* are student characteristics, for example, abilities, attitudes, personality variables, and demographic factors (age, sex, and ethnic background). *Treatments* are forms of instruction or sets of conditions associated with instruction. ATIs refer to differences in student outcomes (e.g., achievement, attitudes) as a function of the interaction (combination) of instructional conditions (treatments) with student characteristics (aptitudes). ATI research examines how individual differences in aptitudes predict students' responses to forms of instruction.

For example, suppose that Karen wanted to know whether large- or small-group instruction (the treatment) produced better achievement in social studies among seventh graders and whether large- and small-group instruction was differentially effective among boys and girls (the aptitude). Karen could randomly assign boys and girls to either a large- or a small-group instructional condition. Assuming that Karen could equate the instructional

content between the large- and small-group conditions, she could test the students following the instructional unit to determine whether (a) a difference existed between large and small groups, (b) a difference existed between boys and girls, and (c) class format interacted with student gender (e.g., girls did equally well under either form of instruction but boys did significantly better in small groups than in large groups). A significant (c) finding would constitute an ATI.

The hypothesis that instructional conditions affect student outcomes differently depending on students' attributes is intuitively plausible (Corno & Snow, 1986). Good teachers know that students need to be treated differently depending on their needs and that any type of instruction will not be equally effective with all students. We saw in the previous section that as teachers develop expertise they tend to plan more instructional adaptations to ensure that all students learn.

ATI research was very active in the years following the information processing breakthrough (mid-1960s to 1980s) but has declined in recent years. We know that student abilities are important predictors of achievement (Kyllonen & Stephens, 1990; Lohman, 1989) and a wealth of research obtained ATIs (Cronbach & Snow, 1977). One reason for the research decline is that many ATI findings have not been replicated in subsequent studies (Cronbach & Snow, 1977). Findings that cannot be replicated may not be reliable. In addition, complex interactions involving three or more variables are difficult to interpret and it may not be clear how to apply these findings to improve teaching and learning.

Tobias (1989) noted that inconsistent ATI results may reflect the idea that treatments require different forms of cognitive processing that may not be inherently linked with other student aptitudes. For example, if Karen obtained an ATI, it implies that the type of cognitive processing required in large- and small-group settings differs; however, the results do not imply that all boys process information better in small groups. Wide individual differences occur in any outcome measure. To determine how these interact with treatments and other aptitudes to influence results, Tobias also recommended including more affective (motivational) variables in ATI studies. Snow et al. (1996) discussed at length research on the interplay of aptitudes and affective variables.

Cognitive Styles

Many researchers interested in learner characteristics have explored cognitive styles. *Cognitive styles* (also known as *learning styles* or *intellectual styles*) are stable individual variations in perceiving, organizing, processing, and remembering information (Shipman & Shipman, 1985; Sigel & Brodzinsky, 1977). Messick (1994) defined them as "modes of perceiving, remembering, thinking, problem solving, and decision making, reflective of information-processing regularities that develop in congenial ways around underlying personality trends" (p. 122). Styles are people's preferred ways to process information and handle tasks (Sternberg & Grigorenko, 1997; Zhang & Sternberg, 2005); they are not synonymous with abilities. Abilities refer to capacities to execute skills; styles are habitual ways of processing and using information.

Styles are inferred from consistent individual differences in organizing and processing information on different tasks (Messick, 1984). To the extent that styles affect cognition, affects, and behavior, they help link cognitive, affective, and social functioning (Messick, 1994). In turn, stylistic differences are associated with differences in learning and receptivity to various forms of instruction (Messick, 1984).

The three major styles discussed below—field dependence–independence, categorization, and cognitive tempo—have substantial research bases and educational implications. There are many other styles including *leveling* or *sharpening* (blurring or accentuating differences among stimuli), *risk taking* or *cautiousness* (high or low willingness to take chances to achieve goals), and *sensory modality preference* (enactive or kinesthetic, iconic or visual, symbolic or auditory) (Sternberg & Grigorenko, 1997; Tobias, 1994). A popular style inventory is the Myers–Briggs Type Indicator (Myers & McCaulley, 1988). This is a personality inventory that purports to show individuals' preferred ways of seeking out learning environments and attending to elements in them. Its four dimensions are extroversion–introversion, sensing–intuitive, thinking–feeling, and judging–perceiving. Readers are referred to Zhang and Sternberg (2005) for in-depth descriptions of other styles.

Styles provide important information about cognitive development. One also can relate styles to larger behavioral patterns to study personality development (e.g., Myers–Briggs). Educators investigate styles to devise complementary learning environments and to teach students more adaptive styles to enhance learning and motivation. Styles also are relevant to brain development and functions (Chapter 9).

Field Dependence–Independence. *Field dependence–independence* (also called *psychological differentiation* and *global and analytical functioning*) refers to the extent that one depends on or is distracted by the context or perceptual field in which a stimulus or event occurs (Sigel & Brodzinsky, 1977; Sternberg & Grigorenko, 1997). The construct was identified and principally researched by Witkin and his colleagues (Witkin, 1969; Witkin, Moore, Goodenough, & Cox, 1977).

Various measures determine reliance on perceptual context. One is the Rod and Frame test, in which the individual attempts to align a tilted luminous rod in an upright position within a tilted luminous frame—inside a dark room with no other perceptual cues. Field independence originally was defined as the ability to align the rod upright using only an internal standard of upright. Other measures are the Embedded Figures test, in which one attempts to locate a simpler figure embedded within a more complex design, and the Body Adjustment test, in which the individual sits in a tilted chair in a tilted room and attempts to align the chair upright. Participants who can easily locate figures and align themselves upright are classified as field independent (Application 7.4).

Young children primarily are field dependent, but an increase in field independence begins during preschool and extends into adolescence. Children's individual preferences remain reasonably consistent over time (Sigel & Brodzinsky, 1977). Data are less clear on gender differences. Although some data suggest that older male students are more field independent than older female students, research on children shows that girls are more field independent than boys. Whether these differences reflect cognitive style or some other construct that contributes to test performance (e.g., activity–passivity) is not clear.

Witkin et al. (1977) noted that field-dependent and -independent learners do not differ in learning ability but may respond differently to learning environments and content. Because field-dependent persons may be more sensitive to and attend carefully to aspects of the social environment, they are better at learning material with social content; however, field-independent learners can easily learn such content when it is brought to their attention. Field-dependent learners seem sensitive to social reinforcement (e.g., teacher

APPLICATION 7.4
Field Dependence and Independence

Elementary teachers must be careful to address the cognitive differences of their children in designing classroom activities, particularly because young children are more field dependent (global) than field independent (analytical). For the primary child, emphasis should be placed on designing activities that address global understanding, while at the same time taking analytical thinking into account.

For example, when Kathy Stone implements a unit on the neighborhood she and her children might initially talk about the entire neighborhood and all the people and places in it (global thinking). The children might build replicas of their homes, the school, churches, stores, and so forth—which could tap analytical thinking—and place these on a large floor map to get an overall picture of the neighborhood (global). Children could think about people in the neighborhood and their major features (analytical thinking), and then put on a puppet show portraying them interacting with one another without being too precise about exact behaviors (global). Mrs. Stone could show a real city map to provide a broad overview (global) and then focus on that section of the map detailing their neighborhood (analytical).

Secondary teachers can take style differences into account in lesson planning. In teaching about the Civil War, Jim Marshall should emphasize both global and analytical styles by discussing overall themes and underlying causes of the war (e.g., slavery, economy) and by creating lists of important events and characters (e.g., Lincoln, Grant, Lee, Battle of Fredericksburg, Appomattox). Student activities can include discussions of important issues underlying the war (global style) and making time lines showing dates of important battles and other activities (analytical style). If Mr. Marshall were to stress only one type of style, students who process and construct knowledge differently may doubt their ability to understand material, which will have a negative impact on self-efficacy and motivation for learning.

praise) and criticism. Field-independent persons are more likely to impose structure when material lacks organization; field-dependent learners consider material as it is. With poorly structured material, field-dependent learners may be at a disadvantage. They use salient features of situations in learning, whereas field-independent learners also consider less salient cues. The latter students may be at an advantage with concept learning when relevant and irrelevant attributes are contrasted.

These differences suggest ways for teachers to alter instructional methods. If field-dependent learners miss cues, teachers should highlight them to help students distinguish relevant features of concepts. This may be especially important with beginning readers as they focus on letter features. Evidence indicates that field-dependent learners have more trouble during early stages of reading (Sunshine & DiVesta, 1976).

Categorization Style. *Categorization style* refers to criteria used to perceive objects as similar to one another (Sigel & Brodzinsky, 1977). Style is assessed with a grouping task in

which one must group objects on the basis of perceived similarity. This is not a cut-and-dried task because objects can be categorized in many ways. From a collection of animal pictures, one might select a cat, dog, and rabbit and give as the reason for the grouping that they are mammals, have fur, run, and so forth. Categorization style reveals information about how the individual prefers to organize information.

Three types of categorization styles are relational, descriptive, and categorical (Kagan, Moss, & Sigel, 1960). A *relational (contextual) style* links items on a theme or function (e.g., spatial, temporal); a *descriptive (analytic) style* involves grouping by similarity according to some detail or physical attribute; a *categorical (inferential) style* classifies objects as instances of a superordinate concept. In the preceding example, "mammals," "fur," and "run" reflect categorical, descriptive, and relational styles, respectively.

Preschoolers' categorizations tend to be descriptive; however, relational responses of the thematic type also are prevalent (Sigel & Brodzinsky, 1977). Researchers note a developmental trend toward greater use of descriptive and categorical classifications along with a decrease in relational responses.

Style and academic achievement are related, but the causal direction is unclear (Shipman & Shipman, 1985). Reading, for example, requires perception of analytic relations (e.g., fine discriminations); however, the types of discriminations made are as important as the ability to make such discriminations. Students are taught the former. Style and achievement may reciprocally influence each other. Certain styles may lead to higher achievement, and the resulting rewards, perceptions of progress, and self-efficacy may reinforce one's continued use of the style.

Cognitive Tempo. *Cognitive (conceptual, response) tempo* has been extensively researched by Kagan and his associates (Kagan, 1966; Kagan, Pearson, & Welch, 1966). Kagan was investigating styles of categorization when he observed that some children responded rapidly and that others were more thoughtful and took their time. Cognitive tempo refers to the willingness "to pause and reflect upon the accuracy of hypotheses and solutions in a situation of response uncertainty" (Shipman & Shipman, 1985, p. 251).

Kagan developed the Matching Familiar Figures (MFF) test to use with children. The MFF is a 12-item match-to-standard test in which a standard figure is shown with six possible matches, one of which is perfect. The dependent variables are time to the first response on each item and total errors across all items. Reflective children score above the median on time (longer) but below the median on errors (fewer), whereas impulsive children show the opposite pattern. Two other groups of children are fast–accurate (below the median on both measures) and slow–inaccurate (above the median on both measures).

Children become more reflective with development, particularly in the early school years (Sigel & Brodzinsky, 1977). Evidence suggests different rates of development for boys and girls, with girls showing greater reflectivity at an earlier age. A moderate positive correlation between scores over a 2-year period indicates reasonable stability (Brodzinsky, 1982; Messer, 1970).

Differences in tempo are unrelated to intelligence scores but correlate with school achievement. Messer (1970) found that children not promoted to the next grade were more impulsive than peers who were promoted. Reflective children tend to perform better on moderately difficult perceptual and conceptual problem-solving tasks and make mature judgments on concept attainment and analogical reasoning tasks (Shipman & Shipman,

1985). Reflectivity bears a positive relationship to prose reading, serial recall, and spatial perspective-taking (Sigel & Brodzinsky, 1977). Impulsive children often are less attentive and more disruptive than reflective children, oriented toward quick success, and demonstrate low performance standards and mastery motivation (Sternberg & Grigorenko, 1997).

Given the educational relevance of cognitive tempo, many have suggested training children to be less impulsive. The Meichenbaum and Goodman (1971) study (Chapter 3) found that self-instructional training decreased errors among impulsive children. Modeled demonstrations of reflective cognitive style, combined with student practice and feedback, seem important as a means of change.

Critique. Cognitive styles seem important for teaching and learning, and a fair amount of research exists that may help guide future efforts and attempts by practitioners to apply findings to improve students' adaptive functioning. For example, learners with a visual–spatial style are better able to process and learn from graphical displays (Vekiri, 2002). At the same time, research on the topic has declined in recent years, and the literature often seems disorganized, which makes attempting to draw conclusions difficult (Miller, 1987). The distinction between cognitive styles and abilities is tenuous and controversial (Tiedemann, 1989); field independence may be synonymous with aspects of intelligence (Sternberg & Grigorenko, 1997). A continuing issue is whether styles are individual traits (relatively permanent) or states (alterable). If styles are ability-driven, then attempts to alter styles may meet with less success than if styles are acquired and subject to change. More-recent research has investigated the organization of styles within information processing frameworks and within the structure of human personality (Messick, 1994; Sternberg & Grigorenko, 1997; Zhang & Sternberg, 2005). These directions may help revive interest in the topic and suggest ways of developing styles in students that facilitate learning.

Learners' Resource Allocations

Learners differ in their limits on information processing capabilities, which has direct implications for instruction. People are limited in how much information they can attend to, rehearse, store in WM, transfer to LTM, and so forth (Chapters 4 and 5). These differences are more apparent in children, but learners of any age demonstrate them.

The *resource allocation model* addresses this issue (Kanfer & Ackerman, 1989; Kanfer & Kanfer, 1991). This model posits that attention is the key cognitive process; through attention, other factors such as abilities, motivation, self-regulation, and perceived task demands affect performance. Attention is a limited resource and is allocated to activities as a function of motivation and self-regulation. *Distal processes* refer to task-related goals and limit total resource availability. *Proximal processes* direct attention to on-task, off-task, or self-regulatory activities. Allocations are adjusted based on feedback about effectiveness. When task demands are high (e.g., difficult goals), people allocate greater attention to the task; conversely, when demands are lower, they may shift some attention away from the task and to other activities. Self-regulation is a central means for producing changes in resource allocation.

Research by Kanfer and others shows how conditions can affect attention allocation. Kanfer and Ackerman (1989) found that task-specific confidence in capabilities (a measure analogous to self-efficacy) is associated with higher levels of self-regulatory activity

and affects resource allocations. As Wood and Bandura (1989) and Jourden, Bandura, and Banfield (1991) have shown, self-efficacy bears an important relation to conceptions of ability; thus, the latter construct may indirectly affect allocation of attention.

The resource allocation model suggests that teachers should make attentional demands appropriate for students during learning and should minimize competing conditions (e.g., distractions). Because motivational factors also are important (e.g., self-efficacy, perceived value), instruction should help build these outcomes to ensure continued allocation of attention to learning tasks. Although the theory needs considerable clarification, it offers a unique perspective for linking instruction and learning.

Adapting Instruction

Ideally, the conditions of instruction will match learners' characteristics; however, this match often does not occur. Learners may need to adapt their styles and preferred modes of working to instructional conditions involving content and teaching methods. Self-regulation methods help learners adapt to changing instructional conditions.

Conversely, instructional conditions can be tailored to individual differences to provide equal learning opportunities for all students despite differences in aptitudes, styles, and so forth (Corno & Snow, 1986; Snow et al., 1996). Expert teachers know ways to adapt instruction to match learners' preferred styles. Macroadaptation occurs at the system or course level and microadaptation at the lesson or segment level.

Macroadaptation. An example of macroadaptation is a college course that uses the Keller Plan (Chapter 2) or similar instructional approach. By allowing students to proceed at their own pace and recycle through material as needed, such courses take into account individual differences in learning ability. Mastery learning programs at the elementary and secondary levels attempt the same.

Two other examples of macro-level adaptive programs are Individually Guided Education (IGE) and the Adaptive Learning Environments Model (ALEM). Under an IGE program, a school determines instructional objectives for each student based on aptitude profiles (e.g., reading, mathematics, motivation). Instruction varies along different dimensions: teacher attention and guidance, amount of time spent interacting with other students and technology, and amount of instruction provided in whole-class and small-group settings (Corno & Snow, 1986). Repeated formative evaluations show how well each student has mastered the objectives, and remedial instruction is given as necessary.

ALEM was designed for elementary students (Wang, 1980). Student assignments in reading and mathematics are individualized according to assessments of entry-level competencies. Quantity and quality of instruction vary depending on student abilities. ALEM makes use of parent involvement, team teaching, and group learning.

Microadaptation. Individual teachers make adaptations with their students during lessons. They provide remedial instruction to students who have difficulty grasping new material. Teachers control many aspects of the instructional environment, which they can tailor to student differences. These aspects include organizational structure (whole-class, small-group, and individual), regular and supplementary materials, use of technology, type of feedback, and type of material presented (tactile, auditory, and visual).

Microadaptation occurs when students work on computer programs that provide additional instruction and practice. Decisions on these individual adaptations often are spontaneous and based on teachers' perceptions of how students react to material. For systematic adaptations, teachers might use measures of ability, learning styles, and motivation during instructional planning to tailor instruction to individual differences (Corno & Snow, 1986).

TECHNOLOGY AND INSTRUCTION

In the last few years, there has been a rapid infusion of technology into instruction (Bonk & King, 1998; Cognition and Technology Group at Vanderbilt, 1996; Fisher, Dwyer, & Yocam, 1996; Grabe & Grabe, 1998a; Jonassen et al., 1999; Roblyer, 2006; Winn, 2002). Technology often is equated with equipment (e.g., computers, CDs, DVDs, VCRs), but its meaning is much broader. *Technology* refers to the designs and environments that engage learners (Jonassen et al., 1999). Research on the effects of technology on learning is increasing, as are efforts to remove barriers to infusing technology into instruction (Ertmer, 1999).

It seems clear that technology has the potential to facilitate instruction in ways that formerly were unimaginable. For example, not long ago technological classroom applications were limited to movies, televisions, slide projectors, radios, and the like. Today, students can experience simulations of environments and events that they never could in regular classes, receive instruction from and communicate with others at long distances, and interact with large knowledge bases and expert tutoring systems. A challenge for researchers is to determine how technology affects learners' cognitive processes during encoding, retention, transfer, and so forth.

This section covers some of the ways that technology is used in instruction, with special emphasis on the link between technology and learning. This material is not a practical guide on how to use technology in education. Readers interested in in-depth applications of technology should consult other sources (e.g., Kovalchick & Dawson, 2004a, 2004b; Roblyer, 2006; Winn, 2002).

Functions of Technology

Technology comprises many applications, but clearly computers figure in many of them. When the computer revolution in education began in the 1980s, a prominent focus area was *computer literacy* (Seidel, Anderson, & Hunter, 1982). At a general level, computer literacy means "the minimum knowledge, know-how, familiarity, capabilities, abilities, and so forth, about computers essential for a person to function well in the contemporary world" (Bork, 1985, p. 33). More specifically, computer literacy can refer to:

- *ability to control and program a computer;*
- *ability to employ preprogrammed computer packages for personal, academic, or business uses;*
- knowing about available hardware and software packages;
- understanding how computers affect individuals, nations, and the world at large;
- knowing how to perform constructive actions with a computer.

Computer literacy is not the major issue that it was formerly, in large part because computers are more readily available and many students learn to use a computer (e.g., Internet, instant messaging) without school instruction (Jonassen, 1996). Today, educators focus on the roles that computers play in teaching and learning, and researchers study the interactions of students with learning environments (Winn, 2002). Although computer learning is not a theory of learning, we might ask whether computers improve school achievement and help develop critical thinking and problem-solving skills, especially in relation to instruction not involving computers.

There is much debate on this topic (Oppenheimer, 1997), with proponents claiming they do and critics asserting they do not. Comparing learning via computers with learning from traditional instruction can be misleading because other factors (e.g., authenticity of the content, teacher–student/student–student interactions) also may differ. Rather than

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Some years ago, Taylor (1980) identified three educational roles for computers: tutor, tool, and tutee. These roles are applicable to all technological applications. Technology as *tutor* presents material to be learned or reviewed, along with evaluative feedback, and decides what material to present next (e.g., expert tutor, software programs). Applications such as videotapes, slides, television, word processing, data analysis, multimedia construction, and computer conferencing represent the *tool* role. Technology functions as *tutee* when students instruct it what to do (e.g., programming, merging files, creating a Web site). These functions do not have clear-cut boundaries; for example, while engaged in word processing (a tool function), students may instruct a Web browser to locate information to be incorporated into the text (a tutee function).

Jonassen et al. (1999) presented a dynamic perspective on the role of technology in learning. The maximum benefits of technology derive when it energizes and facilitates thinking and knowledge construction. In this reconceptualization, technology can serve the functions shown in Table 7.6. The technological applications relevant to learning described in the next section are differentially effective in accomplishing these functions.

Technological Applications

Computer-Based Instruction. Chapter 2 discussed computer-based instruction (CBI) or computer-assisted instruction (CAI) in the context of operant conditioning. Until a few years ago, CBI was the most common application of computer learning in schools

Table 7.6
Functions of technology.

- *Tool* to support knowledge construction.
- *Information vehicle* for exploring knowledge to support learning by constructing.
- *Context* to support learning by doing.
- *Social medium* to support learning by conversing.
- *Intellectual partner* to support learning by reflecting.

Source: Jonassen et al., 1999.

(Jonassen, 1996). CBI is often used for drills and tutorials. Drill programs are easy to write; because they review information, the student proceeds in linear fashion. Tutorials are interactive; they present information and feedback to students and respond based on students' answers. Branching programs are examples of tutorials (Chapter 2).

Studies investigating CBI in college courses found beneficial effects on students' achievement and attitudes (Kulik et al., 1980). Several CBI features are firmly grounded in learning theory and research (Lepper, 1985). Computers command students' attention and provide immediate response feedback. Feedback can be of a type not often given in the classroom, such as how students' present performances compare with their prior performances (to show progress in learning). Computers individualize content and rate of presentation.

Although drills and tutorials place strict limitations on how students can interact with the material, one advantage of CBI is that many programs allow personalization; students enter information about themselves, parents, and friends, which is then included in the instructional presentation. Personalization can produce higher achievement than other formats (Anand & Ross, 1987; Ross et al., 1985). Anand and Ross (1987) gave elementary schoolchildren instruction on dividing fractions according to one of three problem formats (abstract, concrete, and personalized), shown with sample problems:

- [Abstract] There are three objects. Each is cut in half. In all, how many pieces would there be?
- [Concrete] Billy had three candy bars. He cut each one of them in half. In all, how many pieces of candy did Billy have?
- [Personalized for student named Joseph] Joseph's teacher, Mrs. Williams, surprised him on December 15 when she presented Joseph with three candy bars. Joseph cut each one of them in half so that he could share the birthday gift with his friends. In all, how many pieces of candy did Joseph have? (pp. 73–74)

The personalized format led to better learning and transfer than the abstract format and to more positive attitudes toward instruction than the concrete format. Personalizing instruction may improve meaningfulness and facilitate integration of content into LTM networks. Knowledge construction should be aided with familiar referents.

Simulations and Games. *Simulations* represent real or imaginary situations that cannot be brought into the learning setting. Examples are programs simulating the flights of aircraft, underwater expeditions, and life in a fictional city. Learners can build memory networks better when they have tangible referents during learning. *Games* are designed to create an enjoyable learning context by linking material with sport, adventure, or fantasy. Games can emphasize thinking skills and problem solving but also can be used to teach specific content (e.g., basketball game to teach fractions).

Lepper and his colleagues (Lepper, 1985; Lepper & Hodell, 1989) suggested that games also influence learning by increasing motivation. Motivation is greater when an *endogenous* (natural) relationship exists between the content and the means ("special effects") by which the game or simulation presents the content. Fractions are endogenously related to a basketball game, for example, when students are asked to determine how much of the court is covered by players dribbling down the floor. Such an endogenous relationship enhances meaningfulness and LTM coding and storage. In many games and simulations, however, the relation between content and means is arbitrary, such as

when a student's correct response to a question produces fantasy elements (e.g., cartoon characters). When the relation is arbitrary, the game does not produce better learning than traditional instruction, although the former may be more interesting.

As a type of computer-based environment, simulations seem well suited for discovery and inquiry learning. In their review of studies using computer simulations in discovery learning, de Jong and van Joolingen (1998) concluded that simulations were more effective than traditional instruction in inculcating students' "deep" (intuitive) cognitive processing. Simulations also may be beneficial for developing problem-solving skills. Similar to the results for CBI (discussed above), Moreno and Mayer (2004) found that personalized messages from an on-screen agent during simulations improved retention and problem solving better than did nonpersonalized messages. Woodward, Carnine, and Gersten (1988) found that the addition of computer simulations to structured teaching produced problem-solving gains for special education high-school students compared with traditional instruction alone. The authors noted, however, that the mechanism producing these results was unclear and that the results may not generalize to stand-alone computer simulations.

Programming. Computer science courses teach programming skills, which are useful in various occupations. It has been suggested that programming may aid the development of students' thinking, reasoning, and problem-solving skills in ways not possible with standard educational curricula (Jonassen, 1996; Lepper, 1985). Learning to program helps one acquire general problem-solving skills such as formalizing a conceptual model, breaking a larger problem into subproblems, employing a flowchart to determine alternatives, and isolating and correcting conceptual and computational errors (debugging). Programming also exposes children to concepts ordinarily associated with higher-level mathematics (variables and geometric functions), which can be "revisited" periodically during schooling (Bruner, 1960).

Years ago, Papert (1980), a leading computer proponent, described the philosophy of the programming language Logo, which is explicitly designed for children. Through "turtle geometry," children create unusual geometric designs and cartoon drawings by using a small number of simple commands (e.g., "forward," "back," "left turn"). The effects provide children with immediate feedback of efforts to control the environment. In addition, children form commands by using subroutines or sets of commands that produce given configurations. Rather than simply giving the computer a list of instructions, learners combine standard commands with their unique ones.

Empirical evidence is mixed regarding how well computer programming develops thinking and problem-solving skills (Grabe & Grabe, 1998a; Lepper, 1985; Oppenheimer, 1997; Palumbo, 1990). With respect to Logo, research shows that children typically are product oriented and want to generate effects. These outcomes are antithetical to the type of reasoned analysis and careful construction of subroutines required for programming (Grabe & Grabe, 1998a). Although some critics argue that programming results in no learning benefits, Clements and Gullo (1984) obtained positive effects. Six-year-olds were assigned to a programming group or a CBI condition and participated in two 40-min sessions for 12 weeks. The programming group received training on Logo; the CBI group worked on commercial software dealing with reading and mathematics. On a posttest, the programming condition scored higher on measures of reflectivity (cognitive style), divergent thinking (fluency and originality), and metacognition (awareness of comprehension failure).

Working in technological environments involves social interactions, which, based on the writings of Vygotsky (1978) and other social constructivists, should facilitate learning (Winn, 2002). Consistent with this point, researchers have obtained advantages for programming on measures of social behaviors while children worked in pairs during problem solving (e.g., conflict resolution, self-directed work, rule determination), but no advantage for programming on reading or mathematics achievement tests (Clements, 1986; Clements & Nastasi, 1988). Evidence also shows that collaborative efforts among students working on Logo encourage positive social behaviors and constructive attempts to resolve conflicts (Nastasi, Clements, & Battista, 1990). With respect to creativity, Clements (1991, 1995) found that Logo enhanced creativity in both the verbal and the figural domains. Clements (1995) noted, however, that creativity enhancement depends on teacher efforts and that many teachers find it difficult to create a school environment that fosters creativity.

Multimedia/Hypermedia. *Multimedia* refers to technology that combines the capabilities of various media such as computers, film, video, sound, music, and text (Galbreath, 1992); *hypermedia* refers to linked or interactive media (Roblyer, 2006). Multimedia and hypermedia learning occur when students interact with information presented in more than one mode (e.g., words and pictures; Mayer, 1997). The capabilities of computers to interface with other media have advanced rapidly. Video streaming, CDs, and DVDs can be used with computers for instructional purposes (Hannafin & Peck, 1988; Roblyer, 2006).

Multimedia and hypermedia have important implications for teaching because they offer many possibilities for infusing technology into instruction (Dede, 1992; Galbreath, 1992; Hirschbuhl, 1992; Jonassen, 1989; Kozma, 1991; Roblyer, 2006). At the same time, research evidence provides only lukewarm support for the benefits of multimedia for learning. In his review of research studies, Mayer (1997) found that multimedia enhanced students' problem solving and transfer; however, effects were strongest for students with little prior knowledge and high spatial ability. Dillon and Gabbard (1998) also concluded from their review that effects depended in part on ability: Students with lower general ability had the greatest difficulty with multimedia. Learning style was important: Students willing to explore obtained the greatest benefits. Multimedia seems especially advantageous on specific tasks requiring rapid searching through information.

Researchers have investigated the conditions favoring learning from multimedia. When verbal and visual (e.g., narration and animation) information are combined during instruction, students benefit from dual coding (Paivio, 1986; Chapter 4). The simultaneous presentation helps learners form connections between words and pictures because they are in WM at the same time (Mayer, Moreno, Boire, & Vagge, 1999). Multimedia may facilitate learning better than tailoring media to individual student differences (Reed, 2006). By using different media, teachers increase the likelihood that at least one type will be effective for every student. Some instructional devices that assist multimedia learning are (a) text signals that emphasize the structure of the content and its relationship to other material (Mautone & Mayer, 2001), (b) personalized messages that address students and make them feel as participants in the lesson (Mayer, Fennell, Farmer, & Campbell, 2004; Moreno & Mayer, 2000), (c) allowing learners to exercise control over the pace of instruction (Mayer & Chandler, 2001), (d) animations that include movement and simulations (Mayer & Moreno, 2002), (e) being able to interact with an on-screen speaker (Mayer,

Dow, & Mayer, 2003), and (f) being exposed to a human rather than a machine-generated speaker (Mayer, Sobko, & Mantone, 2003).

Maximal benefits of multimedia require that some logistical and administrative issues be addressed. Interactive capabilities are expensive to develop and produce. Costs prohibit many school systems from purchasing components. Interactive video may require additional instruction time because programs present more material and require greater student time in responding. Compared with video alone, interactive video yields higher student achievement, but if the latter requires increased instruction time, it offers no advantage in the amount learned per unit of time (Schaffer & Hannafin, 1986). Many interactive systems are bulky and require a permanent workstation, which can be a problem given that space often is at a premium in schools.

Such elaborate technology may seem overwhelming to many teachers and students, who will require extensive training. The equipment requires maintenance and upgrading, which are problematic when budgets are tight. Despite these issues, multimedia and hypermedia seem to benefit student learning, and research increasingly is showing that this technology can help develop students' self-regulated learning, which in turn leads to more success with the technology (Azevedo, 2005a, 2005b; Azevedo & Cromley, 2004; Azevedo, Guthrie, & Siebert, 2004). Applications will continue to be developed as the technology advances (Roblyer, 2006). Further research is needed on multimedia's effects on motivation and how to link it with a sequence of acquiring self-regulatory skills (e.g., social to self influence; Zimmerman & Tsikalas, 2005; see Chapter 3).

Networking and Distance Learning. Another technological application is *microcomputer networking*. Networks connect microcomputers to one another and to central peripherals (e.g., printers, storage devices). Networking allows schools to be connected with one another and with devices inside and outside of the district. Networking offers several advantages. Students have easy access to computers in their schools. Computer processing takes place in the microcomputer rather than in larger (mainframe) computers. Microcomputers are portable; permanent workstations are not required. Centralized peripheral devices help contain costs. One disadvantage is that when a system becomes excessively large it requires full-time supervision.

Distance learning (distance education) occurs when instruction that originates in one location is transmitted to students at one or more remote sites. If interactive capabilities exist, then two-way feedback and discussions become part of the learning experience. Distance learning saves time, effort, and money because instructors and students do not have to make long journeys to classes. Universities, for example, can recruit students from a wide geographical area. There is less concern about students traveling great distances to attend classes because they are held at a local site (e.g., school district building). Districts can conduct in-service programs by transmitting from a central site to all of the schools. Distance learning sacrifices face-to-face contact with instructors, although if two-way interactive video is used, the interactions are real-time (synchronous). In their review of distance education programs, Bernard et al. (2004) found their effects on student learning and retention comparable to those of traditional instruction. Effects for synchronous instruction favored classroom instruction, whereas distance education was more effective for asynchronous applications (involving lag time).

Another networking application is the *electronic bulletin board (conference)*. People networked with computers can post messages, but more important, learning can be part of a discussion (chat) group. Participants ask questions and raise issues as well as respond to the comments of others. A fair amount of research has examined whether such e-mail exchanges facilitate writing skill acquisition (Fabos & Young, 1999). Whether this asynchronous means of telecommunication exchange promotes learning any better than face-to-face interaction is debatable because much of the research is conflicting or inconclusive (Fabos & Young, 1999); however, the review by Bernard et al. (2004) suggests that distance education may be more effective with asynchronous learning. Telecommunication has the benefit of convenience in that people can respond at any time, not just when they are gathered together. The receptive learning environment may indirectly promote learning.

As forms of *computer-mediated communication (CMC)*, distance learning and computer conferencing greatly expand the possibilities for learning through social interaction. Research should determine whether certain personal characteristics of learners and types of instructional content enhance the benefits of CMC on learning and motivation.

E-Learning. *E-learning* refers to learning through electronically delivered means. The term often is used generally to refer to any type of electronic communication (e.g., videoconferencing); however, here it is used in the narrower sense of Internet (Web-based) instruction.

The *Internet* (an international collection of computer networks) is a system of shared resources that no one owns. The Internet provides access to other people (users) through e-mail and conferences (chat rooms), files, and the World Wide Web (WWW)—a multicomputer interactive multimedia resource. It also stores information that can be copied for personal use (Grabe & Grabe, 1998b).

The Internet is a wonderful resource for information, but we must assess its role in learning. On the surface, the Internet has advantages. Web-based instruction provides students with access to more resources in less time than is possible in traditional ways; however, more resources do not automatically mean better learning. The latter is accomplished only if students acquire new skills, such as methods for conducting research on a topic or critical thinking about the accuracy of material on the Web. Web resources also can promote learning when students take information from the Web and incorporate it into classroom activities (e.g., discovery learning).

In their review of online courses, Tallent-Runnels et al. (2006) found that students liked moving at their own pace, students with more computer experience expressed greater satisfaction, and asynchronous communication facilitated in-depth discussions. Attempting to compare online with traditional courses is difficult because presently most online courses enroll nontraditional and White American students. Clearly, more research is needed on learning outcomes and characteristics of the environment that facilitate learning.

Teachers can assist the development of students' Internet skills with a scaffolding approach. Students must be taught search strategies (e.g., ways to use browsers), but teachers also might conduct the initial Web search and provide students the names of helpful Web sites. Grabe and Grabe (1998b) offer other suggestions.

Web-based learning is commonly incorporated into traditional instruction as a *blended* model of instruction (i.e., some face-to-face instruction and the rest via e-learning). Web-based learning also is useful in conjunction with multimedia projects. In many

teacher preparation programs, preservice teachers use the Web to obtain resources and then selectively incorporate these into multimedia projects as part of lesson designs.

A danger in students using the Internet is that the large array of information available could inculcate the belief that everything is important and reliable. Students then may engage in "associative writing" (Chapter 10) by trying to include too much information in reports and papers. To the extent that e-learning helps teach students the higher-level skills of analysis and synthesis, they will acquire strategies for determining what is important and merging information into a coherent product.

Virtual Reality. *Virtual reality* refers to a computer-based technology designed to provide a simulation of actual settings, which allows students to experience and interact with an artificial environment as if it were the real world (Middleton, 1992; Roblyer, 2006). Virtual-reality systems present a 360°, three-dimensional environment that includes life-like and fantasy elements (i.e., a real world or a fantasy world). Specialized input and output are accomplished through devices for moving in space (e.g., gloves, treadmill, stationary bicycle, bodysuit), mounted displays for visualization, and audio receivers to transmit three-dimensional sound. A feeling of presence in the world is important, so sensors worn by participants (i.e., headgear, bodysuits, data gloves) inform the system of their location, which then varies spatial and audio feedback. Critical features include *flexibility* (ability to present real and unreal worlds), *presence* (sensors and the three-dimensional environment provide users with a sense of being there), *control and interaction* (users can exert control over features of the environment), and *feedback* (users receive sophisticated tactile and temperature feedback).

Virtual reality is a rapidly changing technology. Presently it is not commonly used in education, but several of its features may enhance learning (Lanier, 1992; Middleton, 1992; Roblyer, 2006). Because the world can be changed to meet individual users' needs, it is well designed to accommodate instructional scaffolding and to serve as a medium for apprenticeships. It allows learners to experience phenomena that they cannot in traditional classrooms (e.g., inside of a machine, underground environment). A third application is with physical skills. A virtual-reality world facilitates learning a physical skill because motion can be slowed. This is important for many skills that occur quickly and are difficult to grasp (e.g., juggling) and also for physical therapy patients who are relearning skills (Lanier, 1992). The hope is that virtual reality will stimulate creative thinking by allowing people to test problem solutions in ways not usually possible. Research in this area could foster new teaching methods.

Critique. From the preceding evidence, we can conclude that technology can enhance learning. How technologically enhanced instruction compares with conventional instruction is difficult to assess, and comparisons can present misleading results (Oppenheimer, 1997). No one instructional medium is consistently superior to others, regardless of content, learners, or setting (Clark & Salomon, 1986). Many research studies involving computers suffer from methodological problems involving inadequate comparison groups and the introduction of novelty (Oppenheimer, 1997). When computer learning shows advantages over traditional instruction, it may be because computers present better-prepared materials and implement more effective instructional design strategies. Technology is not a cause of learning; rather, it is a means for applying principles of effective instruction and learning.

Clark and Salomon (1986) recommended that researchers determine the conditions under which computers facilitate instruction and learning. This is still true today and may be said for technology in general. The history of educational reform is littered with changes being adopted prior to any convincing evidence of their effectiveness. Use of technology should depend on the learning goals. Although technology has the potential to foster different learning goals, it may not be the best way to promote student interaction through peer teaching, group discussions, or cooperative learning. Application 7.5 gives some suggestions for infusing technology into classroom instruction.

Even when its use seems beneficial, technology has the disadvantage of not allowing for incidental learning as might occur when a teacher or student mentions in class an anecdote related to the material being studied. Although most Web information is reasonably

APPLICATION 7.5

Technology and Learning

Technological applications can be applied effectively to help improve student learning. Jim Marshall works with an American history teacher in a neighboring high school in developing a Civil War computer simulation. The classes draw straws to determine which class will be the Union and which the Confederacy. The students in each class then study the battles of the Civil War and look for information about the terrain, the weather at the time of each battle, the number of soldiers involved, and the leadership abilities of the individuals in charge. The students in both classes then simulate the battles on the computer, interacting with each other, using the data, trying to see if they might change the outcome of the original battle. When students make a strategic move, they have to defend and support their move with historical data.

Gina Brown uses streaming video and the Web to have her students study and reflect on educational psychology principles applied in classrooms. As students observe the video of an elementary class lesson, they stop the video and enter responses to relate educational practices to psychological principles they have been discussing in class. Then students are able to interact with other students and Dr. Brown to share thoughts on the lesson observed. Dr. Brown also has a fictional classroom set up on a Web site. She poses questions to her students (e.g., "How might the teacher use authentic assessment in science?"), after which they go to the Web site, read and reflect, and construct a response that is distributed to Dr. Brown and all other students. Thus, everyone can respond and interact with others.

Kathy Stone uses her computers for various activities in her third-grade class, but one of the fun activities that incorporates creative writing abilities and word-processing skills becomes a class project each month. At the beginning of each month, Mrs. Stone starts a story on the computer entitled, "The Adventures of Mrs. Stone's Class." Children have the opportunity to add to the story as often as they wish. At the end of the month they print the story and read it aloud in class. The computer provides a unique means for constructing a story collaboratively.

up-to-date, it may need to be supplemented to relate material to current events; after students gather information from the Web on the history and geography of a world region, the teacher and students could discuss the current political situation in the area.

Promising evidence suggests that technological applications can enhance learning, but more research evaluating their effectiveness is necessary. Some research shows that computer-based problem solving is differentially effective for male and female students (Littleton, Light, Joiner, Messer, & Barnes, 1998). Exploring gender and ethnic differences should be a research priority.

Another area that needs to be addressed is the motivational effects of technology on teachers and students (Ertmer, 1999; Lepper & Gurtner, 1989). Lepper and Malone (1987) noted that computers can focus attention on the task through motivational enhancements, maintain level of arousal at an optimal level, and direct students to engage in task-directed information processing rather than attend to focusing on irrelevant task aspects. The idea is that effective motivational principles can enhance *deep* (rather than shallow) *processing* (Hooper & Hannafin, 1991).

Future Directions

Technological developments occur rapidly, and research is sure to accelerate. As technology becomes more elaborate, it will offer a far greater range of instructional possibilities. We will be able to access and create knowledge in new, sophisticated ways. Research will explore the effects of these developments on student learning as well as effective ways to infuse technology into instruction.

Exciting developments are likely on several fronts (Roblyer, 2006). Wireless connectivity now is common, which greatly expands the convenience of using laptop computers in instruction. Wireless and the portability of devices (e.g., laptops, tablets) help instructors infuse technology into instruction. The merging of technologies will continue (e.g., cell phones that can perform multiple functions), which may ultimately lead to students requiring minimal hardware to perform different applications. Technological advances will continue to improve accessibility for persons with disabilities, and assistive technology should become more common in schools. Distance education and online learning opportunities will increase, and with the advent of virtual high schools, e-learning undoubtedly will be expanded to earlier levels (e.g., middle, elementary grades). Finally, as the convenience of technology continues to improve, we may see a gradual moving away from traditional instruction and toward a model containing fewer class meetings and more electronic communications.

At a basic research level, investigations on artificial intelligence (AI) may provide important insights into human learning, thinking, and problem solving. AI refers to computer programs that simulate human abilities to infer, evaluate, reason, solve problems, understand speech, and learn (Trappl, 1985). John McCarthy coined the term in 1956 as a conference theme. Other terms found in the literature (e.g., machine intelligence, intelligent CAI) are roughly synonymous.

AI has three important aspects or goals. First, computers can be programmed to behave in an intelligent manner. These expert systems are increasingly used to solve problems and provide instruction in various domains. A second aspect involves programming computers to simulate human learning and other thought processes with the goal of

understanding the operation of the mind. The third aspect (robotics) investigates how machines can be programmed to perform tasks.

Expert systems are large computer programs that supply the knowledge and problem-solving processes of one or more experts (Anderson, 1990; Fischler & Firschein, 1987; Trappl, 1985). Analogous to human consultants, expert systems have been applied to diverse fields such as medicine, chemistry, electronics, and law. Expert systems have a vast knowledge base consisting of declarative knowledge (facts) and procedural knowledge (system of rules used to draw inferences). An interface poses questions to users and gives recommendations or solutions. A common application of expert systems is to teach by providing expertise to students (Park, Perez, & Seidel, 1987). Instruction often employs guided discovery; students formulate and test hypotheses and experience consequences.

Future expert systems will be applied to a wider array of domains (Self, 1988). One challenge is to improve systems' capabilities to understand natural languages, especially speech. Although expert systems can perform pattern-recognition tasks, most of these tasks involve only visual stimuli. Machines can be programmed to understand a particular human voice. The use of *assistive technology* in education is expanding, as students with disabilities are integrated as much as possible in regular classroom instruction. Expert systems should enhance the capabilities of computers such that they will be accessible to all learners (e.g., auditory, visual, multiple handicaps).

Technology holds exciting possibilities for helping us *understand human thought processes.* This application involves programming computers with some knowledge and rules that allow them to alter and acquire new knowledge and rules based on experiences (Anderson, 1990; Shallis, 1984). In concept learning, for example, a computer might be programmed with an elementary rule and then be exposed to instances and noninstances of the concept. The program modifies itself by storing the new information in memory and altering its rule. Learning also can occur from exposure to case histories. A computer can be programmed with facts and case histories of a disease. As the computer analyzes these histories, it alters its memory to incorporate the etiology, symptoms, and course of the disease. When the computer acquires an extensive knowledge base for a particular disease, it can diagnose future cases with precision.

Technological progress is likely in additional content areas and in the domain of information processing. Computers are built to process information sequentially; humans can process information in parallel (e.g., think of one thing while attending to something else). In a computer, parallel processing can occur by initially dividing a task into subgoals and then assigning subgoals to different processors that are linked. This type of computer activity might provide insight into how pieces of information become linked in thought to provide integrated knowledge.

Robotics is the study of ways to program machines to perform tasks. Robots often conjure up images of humanlike forms in science fiction novels, but most robots in use today are either boxes with mechanical arms and grippers or normal-looking machines (e.g., forklift trucks) without operators. Robots contain sensors that detect light, pressure, sound, and distances, which provide feedback on the location of the robot relative to aspects of its environment. Mechanical hands, arms, wheels, and other devices are used to operate on the environment. The computer may be inside the robot or a mainframe computer linked to the robot by electric wire, cable, or radio. The typical industrial robots can move freely but cannot think or reason. Robots are insensitive to adverse working conditions involving

noise, dust, and dangers; they also do not take long lunch breaks or complain about salaries or working conditions! Future research will most likely focus on making them more economical to build and operate and versatile in task performance.

SUMMARY

This chapter discusses theories of instruction, with particular emphasis on their links to principles of cognitive information processing. Instructional theory historically involved the design of instruction, but with the decline of behaviorism, the focus has broadened to how learner, instructional, and contextual variables operate in educational contexts. Current instructional research investigates the influence of instructional variables on learners' cognitions, how learners construct knowledge, the role of individual differences in learning, and the impact of motivational variables on learning.

Discovery learning allows students to obtain knowledge for themselves through problem solving. Discovery learning is a type of inductive reasoning. It requires that teachers arrange activities such that students can form and test hypotheses; it is not simply letting students do what they want.

Meaningful reception learning of facts, concepts, and principles occurs by relating new information to knowledge in memory. Expository teaching presents information in an organized fashion so it can be incorporated into memory networks. This is a deductive approach: The key is to build hierarchical memory structures where general concepts subsume specific ideas. Advance organizers, or broad statements that introduce lessons, help make learning meaningful. Organizers direct students' attention to important material, highlight interrelations among ideas, and link material to what students know.

Gagné postulated an instructional theory emphasizing the conditions of learning, or the circumstances that prevail when learning occurs. Types of learning outcomes are intellectual skills, verbal information, cognitive strategies, motor skills, and attitudes. Events of learning are factors that make a difference in instruction. Internal events are learners' current capabilities, personal dispositions, and ways of processing information. External events are instructional factors (material and mode of presentation) that support students while they are learning. In designing instruction for intellectual skills, the use of a learning hierarchy specifying component skills and prerequisites is helpful. Some other perspectives on instruction incorporating cognitive and constructivist elements include the time model, mastery learning, inquiry teaching, peer-assisted learning, cognitive load theory, and instruction using worked examples.

Research on teaching shows that teachers' cognitive planning and decision making exert important effects on student learning. An effective instructional model includes components such as specifying learning goals, explaining and demonstrating concepts, monitoring student-guided practice, having students practice independently, and arranging spaced reviews of material.

The role of learner characteristics in teaching is receiving increased emphasis. ATIs involve instructional variables that are differentially effective depending on student characteristics. Cognitive styles are stable variations in perceiving, organizing, processing, and remembering information. Styles serve as bases for adapting instruction to individual differences. Individual differences in learners' attentional allocations also affect instructional

effectiveness and student learning. Teachers often must adapt instruction to student individual differences. Macroadaptations are made at the system or course level, microadaptations at the lesson or segment level.

Technology is assuming an increasingly important role in learning and instruction. A central technological component is the computer. Computer literacy, once a primary focus, has given way to technological learning environments and applications that assist student learning. Some common applications in schools involve CBI, simulations and games, programming, multimedia/hypermedia, networking, distance education, e-learning, and virtual reality. Research evidence on the effects of technology on learning generally is positive, with benefits being obtained for metacognition, deep processing, and problem solving. As technological innovation continues, it is important that researchers determine how technological advances affect student learning and explore AI as a means of understanding human thought.

FURTHER READING

Bruner, J. S. (1961). The act of discovery. *Harvard Educational Review, 31,* 21–32.

Gagné, R. M. (1985). *The conditions of learning* (4th ed.). New York: Holt, Rinehart & Winston.

Roblyer, M. D. (2006). *Integrating educational technology into teaching* (4th ed.). Upper Saddle River, NJ: Merrill/Prentice Hall.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4–14.

Sternberg, R. J., & Grigorenko, E. L. (1997). Are cognitive styles still in style? *American Psychologist, 52,* 700–712.

van Merriënboer, J. J. G., & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational Psychology Review, 17,* 147–177.

Winn, W. (2002). Current trends in educational technology research: The study of learning environments. *Educational Psychology Review, 14,* 331–351.