CHAPTER 10

Content-Area Learning

Kim Danola, a high-school sophomore, is meeting with her counselor Connie Smith. Kim is struggling in school, making Cs and Ds in her courses. Connie knows that Kim can do better in school. Kim's home is full of distractions, and she has a hard time studying there. The two are meeting to discuss a plan to help Kim academically.

Kim: I don't know, my classes are all so different. Algebra, chemistry, history, they don't have anything in common.

Connie: Well I agree they are different subjects. But let's think about it. Do you have a textbook in each class?

Kim: Sure.

Connie: So then in all of them you have to do what?

Kim: Read?

Connie: Sure, read, they all involve reading right?

Kim: Yeah, but the readings are so different. It's like you have to read and study one way in mathematics, a different way in chemistry, and another different way in history.

Connie: Yes, I understand. Kim, there are lots of students in our school that have trouble in these classes. We have student tutors at the school. I'm going to set you up with a tutor for each subject. That student will work with you and show you learning techniques for each subject. But let's go back to what they all have in common. I'm taking a class at the university and I've learned some general study strategies that you can use in all subjects. So I'm going to help you with those.

Kim: Such as?

Connie: Such as checking yourself when you read something to make sure you understood what you read. It's called "comprehension monitoring" and you can do it whenever you read anything. Then there are some other general strategies such as taking notes and summarizing information. These are general skills. You learn them, then you learn how to adapt them to the subject you're studying. I'll help you with those.

Kim: Do you think there's hope for me. My parents are really mad about my grades.

Connie: If I didn't think there was hope, I wouldn't be talking with you. Now let's get started!

The preceding chapters discussed learning processes generically as applicable to diverse content in varied settings. For example, processes such as modeling, encoding, and metacognition apply to many types of learning; they are not unique to certain learners or a few content areas. This is what Connie says in the above scenario.

This chapter examines learning in the content areas of language comprehension, reading, writing, mathematics, science, and social studies. Although generic learning processes apply to these areas, research has shown that content-area learning has unique features. Thus, although mathematics and reading comprehension are aided by goal setting, rehearsal, and problem solving, skill learning in these areas also depends on processes specific to each area. This chapter discusses these domain-specific processes as well as how general processes operate in different domains. Kim's claim that all subjects are different is partially true, but some general study skills are applicable across areas.

This chapter does not cover content areas comprehensively, which is beyond the purpose of this book; indeed, each area could be a separate chapter or book. Rather, it offers a representative sample of learning research in each area. Extensive reviews can be found in other sources (Bruning et al., 2004; Byrnes, 1996; Farnham-Diggory, 1992; Gagné et al., 1993; Mayer, 1992, 1999). In addition, the *Handbook of Research on Teaching* (Richardson, 2001; Wittrock, 1986) and the *Handbook of Educational Psychology* (Alexander & Winne, 2006; Berliner & Calfee, 1996) review learning in these areas and others not covered in this chapter (e.g., second-language learning, moral and values education, arts and aesthetics, and vocational and occupational education).

Unlike much of the earlier research on learning, contemporary work is heavily oriented toward investigating learning with content in actual settings where it occurs. Much content-area learning has addressed expert–novice differences, and researchers also are exploring the strategies that learners use and how these change as skills develop. It remains a challenge to integrate content-area learning with theories of instruction and learning so that a more comprehensive picture can be developed.

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

- Distinguish between general and specific skills and discuss how they work together in the acquisition of competence.
- Describe the novice-to-expert research methodology.
- Explain the major components of language comprehension.
- Define *speech act* and discuss its components.
- Summarize the major principles of reading as demonstrated by research.
- Discuss top-down and bottom-up processing in reading decoding.
- Explain the main processes involved in reading comprehension.
- Sketch a process model of writing and explain the operation of its elements.
- Explain children's computational strategies and how computational skill becomes automatized.
- Discuss the steps involved in mathematical problem solving and some ways that experts and novices differ.
- Describe expert–novice differences in science proficiency and some ways that teachers can foster students' reasoning and conceptual change.
- Explain the skills necessary to develop competence in history and geography.

SKILL ACQUISITION

General and Specific Skills

Skills may be differentiated according to degree of specificity. *General skills* apply to a wide variety of disciplines; *specific skills* are useful only in certain domains. Setting goals and monitoring goal progress, for example, are general skills because they are useful in acquiring a range of cognitive, motor, and social skills. Connie plans to help Kim learn some general skills. Factoring polynomials and solving square-root problems involve specific skills because they have limited mathematical applications. The student tutors will help Kim in specific subjects.

Acquisition of general skills facilitates learning in many ways. Bruner (1985) noted that tasks such as "learning how to play chess, learning how to play the flute, learning mathematics, and learning to read the sprung rhymes in the verse of Gerard Manley Hopkins" (pp. 5–6) are similar in that they involve attention, memory, and persistence.

At the same time, each type of skill learning has unique features. Bruner (1985) contended that views of learning are not unambiguously right or wrong; rather, they can be evaluated only in light of conditions such as the nature of the task to be learned, the type of learning to be accomplished, and the characteristics learners bring to the situation. The many differences between tasks such as learning to balance equations in chemistry and learning to balance on a beam in gymnastics require different processes to explain learning.

Domain specificity is defined in various ways. Ceci (1989) used the term to refer to discrete declarative knowledge structures. Other researchers include procedural knowledge and view specificity as pertaining to the usefulness of knowledge (Perkins & Salomon, 1989). The issue really is not one of proving or disproving one position because we know that both general and specific intellectual skills are involved in learning (Voss, Wiley, & Carretero, 1995). Rather, the issue is one of specifying the extent to which each form of learning involves general and specific skills, what those skills are, and what course their acquisition follows.

Thinking of skill specificity ranging along a continuum is preferable, as Perkins and Salomon (1989) explained:

> General knowledge includes widely applicable strategies for problem solving, inventive thinking, decision making, learning, and good mental management, sometimes called autocontrol, autoregulation, or metacognition. In chess, for example, very specific knowledge (often called local knowledge) includes the rules of the game as well as lore about how to handle innumerable specific situations, such as different openings and ways of achieving checkmate. Of intermediate generality are strategic concepts, like control of the center, that are somewhat specific to chess but that also invite far-reaching application by analogy. (p. 17)

We then can ask: What counts most for ensuring success in learning? Of course, some local knowledge is needed—one cannot become skilled at fractions without learning the rules governing fraction operations (e.g., adding and subtracting). As Perkins and Salomon (1989) noted, however, the more important questions are where are the bottlenecks in developing mastery? Can one become an expert with only domain-specific knowledge? If not, at what point do general competencies become important?

Ohlsson (1993) advanced a model of skill acquisition through practice that comprises three subfunctions: generate task-relevant behaviors, identify errors, and correct errors. This model includes both general and task-specific processes. As learners practice, they monitor their progress by comparing their current state to their prior knowledge. This is a general strategy, but as learning occurs, it becomes increasingly adapted to specific task conditions. Errors often are caused by applying general procedures inappropriately (Ohlsson, 1996), but prior domain-specific knowledge helps learners detect errors and identify the conditions that caused them. With practice and learning, therefore, general methods become more specialized.

Problem solving (discussed in Chapter 5) is useful in much domain-specific learning; however, task conditions often require specific skills for the development of expertise. In many cases, a merging of the two types of skills is needed. Research shows that expert problem solvers often use general strategies when they encounter unfamiliar problems and that asking general metacognitive questions (e.g., "What am I doing now?" and "Is it getting me anywhere?") facilitates problem solving (Perkins & Salomon, 1989). Despite these positive results, general principles often do not transfer (Pressley et al., 1990; Schunk & Rice, 1993). Transfer requires combining general strategies with factors such as instruction on self-monitoring and practice in specific contexts. The goal in the opening scenario is that once Kim learns general strategies, she will be able to adapt them to specific settings.

In short, competence in a domain requires a rich knowledge base that includes the facts, concepts, and principles of the domain coupled with learning strategies that can be applied to different domains and that may have to be tailored to each domain. One would not expect strategies such as seeking help and monitoring goal progress to operate in the same fashion in disparate domains (e.g., calculus and pole vaulting). At the same time, Perkins and Salomon (1989) pointed out that general strategies are useful for coping with atypical problems in different domains regardless of one's overall level of competence in the domain. These findings imply that students need to be well grounded in basic content-area knowledge (Ohlsson, 1993) as well as in general problem-solving and self-regulatory strategies. Application 10.1 provides suggestions for integrating the teaching of general and specific skills.

Novice-to-Expert Research Methodology

The emphasis on learning in content areas has heightened research interest in skill acquisition. This emphasis contrasts with that found in older research on comparisons of methods used to teach reading, writing, arithmetic, and so forth. This historical stress on methods is in part a reflection of the popularity of the conditioning theory explanation of learning as changes in responses because of differential reinforcement (Chapter 2). With the growth of cognitive and constructivist views of learning, researchers have become more interested in students' beliefs and thought processes, and the research focus has shifted accordingly.

To investigate academic tasks, many researchers have used a *novice-to-expert model* with the following steps:

- Identify the skill to be learned.
- Find an expert (i.e., one who performs the skill well) and a novice (one who knows something about the task but performs it poorly).
- Determine how the novice can be moved to the expert level as efficiently as possible.

APPLICATION 10.1
Integrating the Teaching of General and Specific Skills

As teachers work with students, they can effectively teach general skills to increase success in various domains, but they also must be aware of the specific skills that are needed for successful learning within a specific domain.

For example, Kathy Stone might work with her third-grade students on using goal setting to complete assignments. In reading, she might help students determine how to finish reading two chapters in a book by the end of the week. The students might establish a goal to read a certain number of pages or a subsection each day of the week. Because the goal comprises more than just reading the words on the pages, she also must teach specific comprehension skills, such as locating main ideas and reading for details. Goal setting can be applied in mathematics by having students decide how many problems or activities to do each day to complete a particular unit by the end of the week. Specific skills that come into play in this context are determining what the problem is asking for, representing the problem, and knowing how to perform the computations; she must ensure student learning in these areas.

In physical education, students may use goal setting to master skills, such as working toward running a mile in 6 min. The students might begin by running the mile in 10 min and then work to decrease the running time every week. Motor and endurance skills must be developed to successfully meet the goal. Such skills are most likely to be specific to the context of running a short distance in a good time.

The last step often involves computer simulation to identify substeps leading to skill attainment. Between-task similarities occur in the simulations.

This research model is intuitively plausible. The basic idea is that if you want to understand how to become more skillful in an area, closely study someone who performs that skill well. In so doing, you can learn what knowledge he or she possesses, what procedures and strategies are useful, how to handle difficult situations, and how to correct mistakes. The model has many real-world counterparts and is reflected in apprenticeships, on-the-job training, and mentoring. It also helps to use this model when learners pass through intermediate steps in developing competence.

Much of the knowledge on how more- and less-competent persons differ in a domain comes from research based in part on assumptions of the novice-to-expert model (VanLehn, 1996). For this reason, we know a lot about the stages of skill acquisition. Conducting such research is labor intensive and time consuming because it requires studying learners over time, but it yields rich results.

At the same time, this model is descriptive rather than explanatory: It describes what learners do rather than explaining why they do it. The model also tacitly assumes that a fixed constellation of skills exists that constitutes expertise in a given domain, but this is not always the case. With respect to teaching, Sternberg and Horvath (1995) argued that no one standard exists; rather, expert teachers resemble one another in prototypical

fashion. This makes sense given our experiences with master teachers who typically differ in several ways.

Finally, the model does not automatically suggest teaching methods. As such, it may have limited usefulness for classroom teaching and learning. Explanations for learning and corresponding teaching suggestions should be firmly grounded in theories and identify important personal and environmental factors. These factors are emphasized in this and other chapters in this book.

LANGUAGE COMPREHENSION

Our discussion of content domains begins with *language comprehension*, which is a central element for understanding the mind. Although humans and animals have similarities, they differ in many ways and a primary difference is in the acquisition and use of language. The gap between human language and animal communication systems is tremendous. Language is the principal means people use to teach, establish rules, and transmit cultural practices. Language allows us to study human cognition (Carpenter, Miyake, & Just, 1995), perhaps better than any other brain function. This section addresses the components of language comprehension, the role of parsing in comprehension, and the utilization of language.

Components of Comprehension

The research community did not accept Skinner's (1957) explanation of language in terms of reinforcement contingencies (Chapter 2). Chomsky (1959) criticized this approach as unsuitable to explain the richness and diversity of natural languages. Most investigators view language as reflecting cognitive processes, and language research significantly advanced the cognitive revolution in psychology (Carpenter et al., 1995). Much current research explores language processes in schools to include methods of language instruction (Fillmore & Valadez, 1986; Hancock, 2001; Padilla, 2006).

Language comprises both spoken and written communication. Although reading is crucially important in school, children understand spoken language before they learn to read:

> "By the age of three or four, virtually every child has learned a language." You immediately and properly understand the reference to spoken language. The child's linguistic performance matures through adolescence and beyond, but the essential characteristics of adult language appear in the preschooler's speech and comprehension, including a well-developed phonological system, a substantial store of morphemes and rules for adding to that store, a syntax that allows the child to parse and produce the strings of morphemes that relate ideas, and an understanding of the conventions for carrying on a conversation. (Calfee & Drum, 1986, p. 806)

Spoken and written comprehension share certain processes. Speech comprehension is the more basic phenomenon; reading comprehension incorporates additional processes. Anderson (1990) contended that comprehending spoken and written language represents a problem-solving process involving domain-specific declarative and procedural knowledge (production systems).

Comprehension has three major components: perception, parsing, and utilization (Anderson, 1990). *Perception* involves attending to and recognizing an input; in language comprehension, sound patterns are translated into words in working memory (WM). *Parsing* means mentally dividing the sound patterns into units of meaning. *Utilization* refers to the disposition of the parsed mental representation: storing it in long-term memory (LTM) if it is a learning task, giving an answer if it is a question, asking a question if it is not comprehended, and so forth. This section addresses parsing and utilization; Chapter 4 discussed perception (Application 10.2).

Parsing

Linguistic research shows that people understand the grammatical rules of their language, even though they usually cannot verbalize them (Clark & Clark, 1977). Beginning with the work of Chomsky (1957), researchers have investigated the role of deep structures containing prototypical representations of language structure. The English language contains

APPLICATION 10.2

Language Comprehension

Students presented with confusing or vague information may misconstrue it or relate it to the wrong context. Teachers need to present clear and concise information and ensure that students have adequate background information to build networks and schemata.

Assume that Kathy Stone plans to present a social studies unit comparing city life with life in the country but that most of her students have never seen a farm; thus, they will have difficulty comprehending the unit. They may never have heard words such as *silo, milking, sow,* and *livestock.* She can produce better student understanding by providing farm-related experiences: take a field trip to a farm; hatch chicken eggs in the classroom; show films about farm life; or bring in small farm equipment, seeds, plants, small animals, and photographs. As students become familiar with farms, they will be better able to comprehend spoken and written communication about farms.

Young children may have difficulty following directions in preschool and kindergarten. Their limited use and understanding of language may cause them to interpret certain words or phrases differently than intended. For instance, if a teacher said to a small group of children playing in a "dress-up" center, "Let's get things tied up so we can work on our next activity," the teacher might return to find children tying clothes together instead of cleaning up! Or a teacher might say, "Make sure you color this whole page," to children working with crayons. Later the teacher may discover that some children took a single crayon and colored the entire page from top to bottom instead of using various colors to color the items on the page. Teachers must be careful to explain, demonstrate, and model what they want children to do. Then they can ask the children to repeat in their own words what they think they are supposed to do.

a deep structure for the pattern "noun 1–verb–noun 2," which allows us to recognize these patterns in speech and interpret them as "noun 1 did verb to noun 2." Deep structures may be represented in LTM as productions (if–then statements). Chomsky postulated that the capacity for acquiring deep structures is innately human although which structures are acquired depends on the language of one's culture.

Parsing includes more than just fitting language into production systems. When people are exposed to language, they construct a mental representation of the situation. They recall from LTM propositional knowledge about the context, into which they integrate new knowledge. A central point is that *all communication is incomplete.* Speakers do not provide all information relevant to the topic being discussed. Rather, they omit the information listeners are most likely to know (Clark & Clark, 1977). For example, suppose Sam meets Kira and Kira remarks, "You won't believe what happened to me at the concert!" Sam is most likely to activate propositional knowledge in LTM about concerts. Then Kira says, "As I was locating my seat. . . ." To comprehend this statement, Sam must know that one purchases a ticket with an assigned seat. Kira did not tell Sam these things because she assumed he knew them.

Effective language parsing requires knowledge and inferences (Resnick, 1985). When exposed to verbal communication, individuals access information from LTM about the described situation. This information exists in LTM as propositional networks hierarchically organized as *schemata* (prototypical versions of situations). Networks allow people to understand incomplete communications. Consider the following sentence, "I went to the grocery store and wrote a check for $25 over the amount." Knowledge that people buy merchandise in grocery stores and that they may write checks to pay for it enables listeners to comprehend this sentence. The missing information is filled in with knowledge in memory.

People often misconstrue communications because they fill in missing information with the wrong context. When given a vague passage about four friends getting together for an evening, music students interpreted it as a description of playing music, whereas physical education students described it as an evening of playing cards (Anderson, Reynolds, Schallert, & Goetz, 1977). The interpretative schemata salient in people's minds are used to comprehend problematic passages. As with many other linguistic skills, interpretations of communications become more reliable with development as children realize the intent of a message as well as its content (literal meaning; Beal & Belgrad, 1990).

That spoken language is incomplete can be shown by decomposing communications into propositions and identifying how propositions are linked. Consider the following example (Kintsch, 1979):

> The Swazi tribe was at war with a neighboring tribe because of a dispute over some cattle. Among the warriors were two unmarried men named Kakra and his younger brother Gum. Kakra was killed in battle.

Although this passage seems straightforward, analysis reveals the following 11 distinct propositions:

1. The Swazi tribe was at war.
2. The war was with a neighboring tribe.
3. The war had a cause.

4. The cause was a dispute over some cattle.
5. Warriors were involved.
6. The warriors were two men.
7. The men were unmarried.
8. The men were named Kakra and Gum.
9. Gum was the younger brother of Kakra.
10. Kakra was killed.
11. The killing occurred during battle.

Even this propositional analysis is incomplete. Propositions 1 through 4 link together, as do Propositions 5 through 11, but a gap occurs between 4 and 5. To supply the missing link, one might have to change proposition 5 to "The dispute involved warriors."

Kintsch and van Dijk (1978) showed that features of communication influence comprehension. Comprehension becomes more difficult when more links are missing and when propositions are further apart (in the sense of requiring inferences to fill in the gaps). When much material has to be inferred, WM easily becomes overloaded and comprehension suffers.

Just and Carpenter (1992) formulated a *capacity theory of language comprehension*, which postulates that comprehension depends on WM capacity and individuals differ in this capacity. Elements of language (e.g., words and phrases) become activated in WM and can be operated on by other processes. If the total amount of activation available to the system is less than the amount required to perform a comprehension task, then some of the activation maintaining older elements will be lost (Carpenter et al., 1995), for example, elements comprehended at the start of a lengthy sentence may be lost by the end. Production-system rules presumably govern activation and the linking of elements in WM.

We see the application of this model in parsing of ambiguous sentences or phrases (e.g., "The soldiers warned about the dangers . . ."; MacDonald, Just, & Carpenter, 1992). Although alternative interpretations of such constructions initially may be activated, the duration of maintaining them depends on WM capacity. Persons with large WM capacities maintain the interpretations for quite a while, whereas those with smaller capacities typically maintain only the most likely (although not necessarily correct) interpretation. With increased exposure in the linguistic context, comprehenders can decide which interpretation is correct, and such identification is more reliable for persons with large WM capacities who still have the alternative interpretations in WM (Carpenter et al., 1995; King & Just, 1991).

In building representations, people include important information and omit details (Resnick, 1985). These *gist representations* include propositions most germane to comprehension. Listeners' ability to make sense of a text depends on what they know about the topic (Chiesi et al., 1979; Spilich et al., 1979). When the appropriate network or schema exists in listeners' memories, they employ a production that extracts the most central information to fill the slots in the schema. Comprehension proceeds slowly when a network must be constructed because it does not exist in LTM.

Stories exemplify how schemata are employed. Stories have a prototypical schema that includes setting, initiating events, internal responses of characters, goals, attempts to attain goals, outcomes, and reactions (Black, 1984; Rumelhart, 1975, 1977; Stein & Trabasso,

1982). When hearing a story, people construct a mental model of the situation by recalling the story schema and gradually fitting information into it (Bower & Morrow, 1990). Some categories (e.g., initiating events, goal attempts, and consequences) are nearly always included, but others (internal responses of characters) may be omitted (Mandler, 1978; Stein & Glenn, 1979). Comprehension proceeds quicker when schemata are easily activated. People recall stories better when events are presented in the expected order (i.e., chronological) rather than in a nonstandard order (i.e., flashback). When a schema is well established, people rapidly integrate information into it. Research shows that early home literacy experiences that include exposure to books relate positively to the development of listening comprehension (Sénéchal & LeFevre, 2002).

Utilization

Utilization refers to what people do with the language communications they receive. For example, if the communicator asks a question, listeners retrieve information from LTM to answer it. In a classroom, students link the communication with related information in LTM.

To utilize sentences as speakers intend properly, listeners must encode three pieces of information: speech act, propositional content, and thematic content. A *speech act* is the speaker's purpose in uttering the communication or what the speaker is trying to accomplish with the utterance (Austin, 1962; Searle, 1969). Speakers may be conveying information to listeners, commanding them to do something, requesting information from them, promising them something, and so forth. *Propositional content* is information that can be judged true or false (Chapter 4). *Thematic content* refers to the context in which the utterance is made. Speakers make assumptions about what listeners know. On hearing an utterance, listeners infer information not explicitly stated but germane to how it is utilized. The speech act and propositional and thematic contents are most likely encoded with productions.

Clark and Clark (1977) summarized utilization as follows:

> 1. On hearing an utterance, listeners identify the speech act, propositional content, and thematic content.
> 2. They next search memory for information that matches the given information.
> 3. Depending on the speech act, they deal with the new information:
>   a. If the utterance is an assertion, they add the new information to memory.
>   b. If the utterance is a yes/no question, they compare the new information with what is in memory and, depending on the match, answer yes or no.
>   c. If the utterance is a WH question, they retrieve the wanted information from memory and compose an answer conveying that information.
>   d. If the utterance is a request, they carry out the action necessary to make the new information true. (p. 90)

As an example of this process, assume that Jim Marshall is giving a history lesson and is questioning students about text material. Marshall asks, "What was Churchill's position during World War II?" The speech act is a request and is signaled by the sentence beginning with a WH word (e.g., who, which, where, when, and why). The propositional content refers to Churchill's position during World War II; it might be represented in memory as follows: Churchill–Prime Minister–Great Britain–World War II.

The thematic content refers to what the teacher left unsaid; the teacher assumes students have heard of Churchill and World War II. Thematic content also includes the classroom question-and-answer format. The students understand that Marshall will be asking questions for them to answer.

Of special importance for school learning is how students encode assertions. When teachers utter an assertion, they are conveying to students they believe the stated proposition is true. If Marshall says, "Churchill was the Prime Minister of Great Britain during World War II," he is conveying his belief that this assertion is true. Students record the assertion with related information in LTM.

Speakers facilitate the process whereby people relate new assertions with information in LTM by employing the *given-new contract* (Clark & Haviland, 1977), the terms of which are as follows:

> The speaker agrees (a) to use given information to refer to information she thinks the listener can uniquely identify from what he already knows and (b) to use new information to refer to information she believes to be true but is not already known to the listener. (Clark & Clark, 1977, p. 92)

The given-new contract says that given information should be readily identifiable and new information should be unknown to the listener. We might think of the given-new contract as a production. In integrating information into memory, listeners identify given information, access it in LTM, and relate new information to it (i.e., store it in the appropriate "slot" in the network). For the given-new contract to enhance utilization, given information must be readily identified by listeners. When given information is not readily available because it is not in listeners' memories or has not been accessed in a long time, using the given-new production is difficult.

Although language comprehension is often overlooked in school in favor of reading and writing, it is a central component of literacy. Educators lament the poor listening and speaking skills of students, and these are valued attributes of leaders. Habit 5 of Covey's (1989) *Seven Habits of Highly Effective People* is "Seek first to understand, then to be understood," which emphasizes listening first and then speaking. Listening is intimately linked with high achievement. A student who is a good listener is rarely a poor reader. Among college students, measures of listening comprehension may be indistinguishable from those of reading comprehension (Miller, 1988). Reading—a second critical component of literacy and one in which volumes of research have been conducted—is considered next.

READING

As with language comprehension, *reading* involves perception, parsing, and utilization. The perceptual part of reading (recognizing words) is referred to as *lexical access* or *decoding*. *Comprehension*, or the attachment of meaning to printed information, involves parsing and utilization.

There is a vast amount of reading research. There also is much debate in the field over how reading should be conceptualized, for example, in terms of schemata or as social and cultural processes (McVee, Dunsmore, & Gavelek, 2005). Both undoubtedly are important.

This section is selective and covers only basic information on learning to read. Readers interested in exploring the field in greater depth should consult other sources (Alvermann, Fitzgerald, & Simpson, 2006; Armbruster & Osborne, 1999; Barr, 2001; McVee et al., 2005).

Reading research has substantiated the validity of four major principles (Hall, 1989). First, skilled reading is a complex task that involves perceptual, cognitive, and linguistic processes (Hiebert & Raphael, 1996). Second, reading is interactive in the sense that readers derive information from many levels (e.g., phonemic, morphemic, semantic, syntactic, pragmatic, and interpretative) rather than proceeding sequentially from basic decoding to comprehension. Third, the human information processing system limits our capacity for processing text (e.g., attention, perception, WM, and LTM). When lower-level processes (decoding) function automatically, this frees up more space for higher-level functions. Fourth, reading is strategic (Guthrie et al., 2004). Good readers set goals, select strategies, and monitor progress; in short, they are metacognitively active (Byrnes, 1996). Most children with learning disabilities display reading problems (Browder, Wakeman, Spooner, Ahlgrim-Delzell, & Algozzine, 2006), and these stem largely from shortcomings in strategic processing and metacognition (Gersten, Fuchs, Williams, & Baker, 2001). We now turn to a discussion of component processes.

Decoding

Decoding means deciphering printed symbols or making letter-sound correspondences by using a whole-word (matching/pattern recognition) or a phonetic (sound-out/recoding) approach (Gagné et al., 1993). In the *whole-word approach*, the printed word is matched to a similar pattern in LTM, which activates the word's meaning for comprehension. This approach relies on pattern-recognition procedures; the patterns are in one's sight vocabulary. In the *phonetic approach*, one sounds out a word by dividing it into syllables and generating corresponding sound patterns. The phonetic patterns activate the word's meaning in memory. Regardless of approach, word recognition is a critical aspect of beginning reading instruction (Biemiller, 1994; Mayer, 1999), and is a key component used in labeling a child as a good reader (Hammill, 2004).

The phonetic and whole-word techniques employ bottom-up and top-down processing, respectively (Just & Carpenter, 1980; Resnick, 1985). In *bottom-up* (or *data-driven*) *processing* (Bruning et al., 2004), people recognize features of letters, combine letters into syllables, and combine syllables into words. Word recognition precedes meaning. Reading is controlled by the printed input. Less-skilled readers often employ bottom-up processing, and it is used by good readers when they encounter unfamiliar words.

In *top-down* (or *conceptually driven*) *processing* (Bruning et al., 2004), readers create a context based on prior knowledge and current information. Reading is controlled by higher-level processes such as forming expectations about what will occur and drawing inferences. The context is made up of propositional networks and schemata with empty slots. Readers fill in the required information and confirm or disconfirm hypotheses about what will occur. They employ production systems to extract the expected information from text. With efficient top-down processing, readers do not encode separate words but rather propositions or larger units.

Figure 10.1 shows examples of top-down and bottom-up processing. Assume that a student has been reading a passage about a tall boy. The reader encounters the sentence,

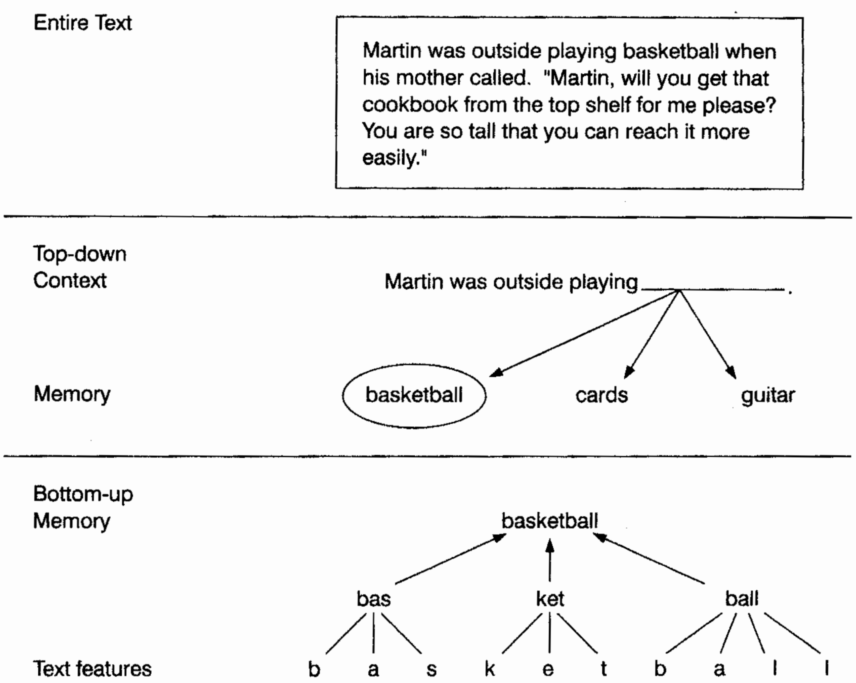


Figure 10.1
Examples of top-down and bottom-up processing.

"Martin was outside playing _____." Using top-down processing, the reader might expect to find the word *basketball*. With bottom-up processing, the reader would construct the word from individual syllables.

In skilled reading, much information is processed automatically. ***Automaticity*** of word recognition, rather than actual recognition, distinguishes good from poor readers. Automatic processing is important because the WM has a limited capacity (Calfee & Drum, 1986). Readers can rapidly transfer information in WM to LTM and move to new material (Resnick, 1985).

Gough (1972) developed an eye-tracking model of reading comprehension. In studies of eye fixations during reading, good readers spend significantly less time on both unfamiliar and familiar words (Just & Carpenter, 1980). The former also sound out unfamiliar words faster than the latter. Good readers tend to parse passages at the end of phrases and sentences; they pause longer there than in the middle. They integrate information at natural break points (units of thought), which helps them draw inferences and construct meaning. Children with poor phonological skills adopt less-than-optimal reading strategies, which then result in low performance (Tunmer & Chapman, 1996).

Although speed in reading does not guarantee total comprehension, a moderately positive relation exists between decoding speed and comprehension skill (Curtis, 1980). Rapid decoding seems to activate learners' comprehension processes sooner so that they comprehend more information in less time. Slow decoding takes more time to activate comprehension processes; in the meantime, some information previously decoded is lost from WM and

is inaccessible for comprehension. de Jong (1998) concluded that children with reading disabilities have great difficulty concurrently processing and storing information.

Correlational data do not imply causality; an ability may correlate highly with reading but not cause it (Hammill, 2004). However, the evidence suggests that children who have decoding problems also have difficulty learning to comprehend. Educational researchers and practitioners advocate that children be able to decode largely automatically (Adams, 1990). Readers who spend time and mental effort decoding do not have the proper mental resources to comprehend what they read. This suggestion does not commit one to a particular method of reading instruction (e.g., phonics and whole language; Gagné et al., 1993). There are proponents for each. Developing decoding skills requires practice and feedback, which helps to build reading self-efficacy (Tunmer & Chapman, 2002). Application 10.3 gives suggestions for teaching decoding.

APPLICATION 10.3

Teaching Decoding

Teachers must work with young readers in helping them develop various decoding skills. A first-grade teacher might help young children learn to read new material by asking key questions that students can use as they develop the techniques. When children have trouble with a specific word, the teacher might encourage top-down processing by asking:

- What word might make sense in the sentence? Read the sentence again and see if you can think of one.
- What was being talked about in the sentence? What might you expect to happen?
- Close your eyes and imagine what is happening. Now what might you expect to see next?

Alternatively, the teacher might encourage bottom-up processing with these questions:

- Do you see any little words you know inside this word?
- Does this word look like any other word you know?
- Can you sound out the letters in this word to make the whole word?

Jim Marshall is working with small groups in his U.S. history class as they develop a skit depicting a scene that might have occurred during the Great Depression. As he works with the students, he encourages them to close their eyes and visualize a scene that could have been a great concern to a family during that time. They might try visualizing and thinking about these questions:

- What areas of life (e.g., jobs and schooling) were affected by the Great Depression?
- What hardships were caused by the Great Depression?
- What compromises did families have to make to adjust to the hardships created by the Great Depression?
- How did the Great Depression affect relationships within the family?
- How did the Great Depression affect friendships?

Comprehension

Basic Processes. *Comprehension* involves attaching meaning to printed information and using the information for a particular purpose. Successful comprehension requires conceptual understanding, automated basic skills, and effective use of strategies (Byrnes, 1996; Gagné et al., 1993; Mayer, 1999). Different levels of comprehension exist (Perfetti, 1985). At a basic level, readers access a word's meaning as a consequence of decoding. At a higher level, readers move beyond the literal meaning of printed words and engage in mental activities, such as drawing inferences, deciding on main ideas, inferring the writer's purpose or bias, and anticipating how events will unfold in text.

Once a word is decoded, readers access the meaning stored with the letter–sound correspondence in LTM. Understanding word meanings depends on one's store of declarative knowledge. Proficient readers have rich vocabularies and fast access to word meanings, which relate positively to reading comprehension (Goldberg, Schwartz, & Stewart, 1977).

Comprehension is influenced by the reading context (Hiebert & Raphael, 1996). Good readers employ top-down processing more than poor readers and are faster in part because they usually rely on context to identify words. Skilled readers also take advantage of word context to parse sentences into natural units, even when punctuation marks are absent. Readers derive contextual cues that signal where units are to be parsed, such as word order, word endings, and punctuation. In the sentence, "The plodols went home," readers will not know the meaning of "plodols" (there is no such word) but will surmise that it is a plural noun because it follows "the" in the first position of the sentence and because it ends in "s."

Goodman (1982) felt that readers use text as a means of confirming or not confirming predictions about what the text is going to say (a top-down model). Four cycles occur interactively: optical (receiving the visual input), perceptual (identifying letters and words), syntactic (identifying structure of the text), and meaning (constructing meaning for the input). Once reading begins, readers construct an initial meaning for the text, which serves as the basis for predictions of future input. Reading continues as predictions are confirmed, but the reader slows down or rereads to get a better meaning if the initial prediction is incorrect. Errors (miscues), therefore, are fairly common and actually can facilitate comprehension.

Literal comprehension is important for reading texts such as a restaurant menu or directions for assembling a bookcase. People often find that they must go beyond literal meaning to understand better what they are reading. *Inferential comprehension* is involved in activities such as identifying main ideas, getting the gist, summarizing and integrating information, and drawing conclusions. Inferential comprehension requires mentally linking different ideas in text. Consider the following sentences:

- The Senate failed to ratify the treaty.
- Senator Milhoudy was livid.

These sentences are linked in the sense that both refer to the Senate, but their meanings are not linked. A reader might infer that the reason Senator Milhoudy was livid was because the senator wanted the treaty ratified and voted to ratify it but the vote failed in the Senate.

Compared with poor readers, skilled readers integrate ideas better within and between sentences (Perfetti & Roth, 1981). For example, skilled readers are quicker to determine a pronoun's referent, whereas poor readers benefit when noun phrases are repeated.

Another inferential comprehension process is *summarization* or grouping important points into a coherent structure by drawing inferences and using words and phrases that signal main ideas (e.g., "in summary"; Kintsch & van Dijk, 1978). Good readers are more proficient at summarizing than poor readers (Meyer, Brandt, & Bluth, 1980). The ability to identify and use structure improves with development.

Skilled readers are more knowledgeable about how texts are organized and are better equipped with strategies for acquiring information to complement the organization than poor readers. Poor readers also do not utilize strategies effectively (Cataldo & Cornoldi, 1998). Skilled readers have mental schemata representing prototypical organizations of texts (Meyer, 1984). A text may compare and contrast, discuss cause and effect, show how ideas are related, state an idea or principle with examples, or present a problem with solutions. When reading, skilled readers identify the text pattern, access the schema from LTM, and integrate information from text into the appropriate schema slots.

Inferential comprehension also involves *elaboration* or adding to new knowledge by using prior knowledge. Following are some ways to elaborate new knowledge:

- Think of examples of the ideas or principles described.
- Anticipate what will happen in the story.
- Fill in missing details in text.
- Draw an analogy between new material and what is known.
- Think about implications of what is stated.
- Relate details to main ideas.
- Compare ideas to your beliefs.

Elaborations help link new information to organizational structures already in memory. Skilled readers are more facile at employing elaborations than poor readers.

Metacognition. *Metacognition* (Chapter 5) is relevant to reading because it is involved in understanding and monitoring of reading purposes and strategies (Paris, Wixson, & Palincsar, 1986). Beginning readers often do not understand the conventions of printed material: In the English language, one reads words from left to right and top to bottom. Beginning and poorer readers typically do not monitor their comprehension or adjust their strategies accordingly (Baker & Brown, 1984). Older and skilled readers are better at comprehension monitoring than younger and less-skilled readers, respectively (Alexander et al., 1995; Paris et al., 1986).

Metacognition is involved when learners set goals, evaluate goal progress, and make necessary corrections (McNeil, 1987). Skilled readers do not approach all reading tasks identically. They determine their goal: find main ideas, read for details, skim, get the gist, and so forth. They then use a strategy they believe will accomplish the goal. When reading skills are highly developed, these processes may occur automatically.

While reading, skilled readers check their progress. If their goal is to locate important ideas, and if after reading a few pages, they have not located any important ideas, they are apt to reread those pages. If they encounter a word they do not understand, they try to determine its meaning from context or consult a dictionary rather than continue reading.

Developmental evidence indicates a trend toward greater recognition and correction of comprehension deficiencies (Alexander et al., 1995; Byrnes, 1996; Garner & Reis, 1981). Younger children recognize comprehension failures less often than do older children. Younger children who are good comprehenders may recognize a problem but may not employ a strategy to solve it (e.g., rereading). Older children who are good comprehenders recognize problems and employ correction strategies.

Children develop metacognitive abilities through interactions with parents and teachers (Langer & Applebee, 1986). Adults help children solve problems by guiding them through solution steps, reminding them of their goal, and helping them plan how to reach their goal. An effective teaching procedure includes informing children of the goal, making them aware of information relevant to the task, arranging a situation conducive to problem solving, and reminding them of their goal progress.

Because many children do not use effective strategies, researchers have recommended teaching strategies. The opening scenario highlights the role of effective strategy use in learning. *Strategy instruction* programs generally have been successful in helping students learn strategies and maintain their use over time (Pressley & Harris, 2006). Brown and her colleagues advocate strategy training incorporating practice in use of skills, instruction in how to monitor outcomes of one's efforts, and feedback on when and where a strategy may be useful (Brown, 1980; Brown, Palincsar, & Armbruster, 1984).

Palincsar and Brown (1984) identified seventh graders with poor comprehension skills. They trained students in self-directed summarizing (review), questioning, clarifying, and predicting. Summarizing included stating what had happened in the text and also served as a self-test on the content. Questioning addressed determining what main idea question a teacher or test might ask about that material. Clarifying was used when portions of the text were unclear and students could not adequately summarize. Predicting was used when text cues signaled forthcoming information.

Researchers taught these activities as part of an interactive dialogue between teacher and student known as *reciprocal teaching*. During the lessons, an adult teacher met with two students. Initially, the teacher modeled the activities. The teacher and students silently read a passage, after which the teacher asked a question that a teacher or test might ask, summarized the content, clarified troublesome points, and predicted future content. Following the teacher's modeled demonstration, the teacher and students took turns being the teacher. At first, students had difficulty assuming the role of teacher; the teacher often had to construct paraphrases and questions for students. Eventually, students became more capable of following the procedure and implementing the four activities.

Compared with a condition in which students received instruction on locating information in text, reciprocal teaching led to greater comprehension gains, better maintenance over time, and better generalization to classroom comprehension tests. Students exposed to reciprocal teaching also showed greater improvements in quality of summaries and questions asked. The maintenance and generalization results are important because changes brought about by strategy training programs often do not maintain themselves or generalize to other tasks (Phye, 2001).

The dialogue about the following text occurred between teacher (T) and student (S) early in the training program (Palincsar & Brown, 1984).

> The snake's skeleton and parts of its body are very flexible—something like a rubber hose with bones. A snake's backbone can have as many as 300 vertebrae, almost 10 times as many

as a human's. These vertebrae are connected by loose and rubbery tissues that allow easy movement. Because of this bendable, twistable spinal construction, a snake can turn its body in almost any direction at almost any point.

S: Like, if a snake is turning around, he wouldn't break any bones because he is flexible.

T: And the reason he is so flexible is . . .

S: If someone stepped on his tail, he wouldn't be able to move unless he was flexible.

T: O.K. That explains why it would be helpful to be so flexible, but what makes the snake so flexible? I think that is an important part of the summary.

S: So he can move faster?

T: That is another reason for being flexible. Let me do a summary for you. Sara [the student] is right. The most important thing we have learned is that snake[s are] very flexible. The reason they can bend so easily is that they have so many little bones in their backbones and each of them can move separately, making the snake very flexible. Does that make sense? (p. 142)

The last statement by the teacher is a modeled demonstration of summarization.

There are many other examples of reading programs that incorporate strategy instruction and teach students to self-regulate their reading. For example, the *Self-Regulated Strategy Development* program combines strategy instruction with instruction in self-regulation (e.g., self-monitoring, self-instructions, goal setting, and self-reinforcement; Graham & Harris, 2003; Mason, 2004). This program has proven to be effective with children with learning disabilities and reading problems.

The *Informed Strategies for Learning* (ISL) program by Paris and his colleagues (Paris et al., 1984; Paris & Oka, 1986) includes strategy training incorporating metacognitive elements. ISL is based on the premise that reading requires declarative, procedural, and conditional knowledge. The program also attempts to enhance students' self-efficacy for effectively applying strategies. Children exposed to this program typically show gains in awareness of comprehension strategies and monitoring skills, which in turn bear a positive relationship to reading achievement. The program benefits students with high-, average-, and low-reading abilities, which enhances its potential for classroom use.

Concept-Oriented Reading Instruction (CORI) incorporates cognitive strategy instruction on the strategies of activating background knowledge, questioning, searching for information, summarizing, organizing graphically, and identifying story structure (Guthrie et al., 2004; Guthrie, Wigfield, & Perencevich, 2004). CORI has shown to be effective in raising students' reading comprehension.

Motivation plays a critical role in reading comprehension (Schunk, 1995). Guthrie, Wigfield, and VonSecker (2000) integrated reading strategy instruction with science content and found significant benefits on students' motivation compared with traditional instruction emphasizing coverage of material. Student interest presumably was heightened with the real-world use of effective reading strategies. The CORI program also incorporates motivational practices such as goal setting and giving students choices. Compared with strategy instruction alone, Guthrie et al. (2004) found that CORI led to greater benefits in comprehension, motivation, and use of strategies.

Other research shows that motivational factors can affect reading outcomes. Meece and Miller (2001) found that task-mastery goals predicted students' use of learning strategies in reading instruction. After reviewing a large number of studies, Blok, Oostdam,

Otter, and Overmaat (2002) concluded that computer-assisted instruction was effective in beginning reading instruction. It is possible that the motivational benefits of computers may aid in the development of early reading skill, but the issue requires additional investigation.

The rapid influx of non-native English-speaking students in U.S. schools has necessitated expansion of programs for English language learners. For English instruction, students often are placed in immersion or second-language programs. In immersion programs, students learn English in an all-English-speaking classroom with formal or informal support when they have difficulties. In second-language programs, students receive instruction in reading and possibly other subjects in their native languages. Students often transition to English instruction around grade 2 or 3. Slavin and Cheung (2005) compared immersion with second-language programs and found an advantage of second-language programs on students' reading competencies; however, the number of studies in their review was small, and longitudinal studies are needed to determine long-term effects.

WRITING

Another important component of literacy is writing. *Writing* refers to translating ideas into linguistic symbols in print. Reading and writing utilize many of the same cognitive processes although reading is somewhat easier than writing (Fitzgerald & Shanahan, 2000). Relative to reading, less research has been conducted on writing. In part, historical reluctance to investigate writing may have stemmed from the erroneous beliefs that good writers are born rather than made and that, because good writing is creative and inspirational, words should flow with little effort. Contemporary research has debunked these myths by showing that excellence in writing, as with excellence in other domains, can be developed and that effective instruction is critical (Flower, 1981; Flower & Hayes, 1980; Graham, 2006; Harris, Graham, & Mason, 2006; Scardamalia & Bereiter, 1986; Sperling & Freedman, 2001).

Early models subdivided writing into stages such as prewriting, writing, and rewriting (Rohman, 1965). One benefit of these stage models is that they call attention to the phases of writing. Good writers do not simply spew forth words; they spend much time thinking and organizing their thoughts and rewriting what they have written. At the same time, writing does not seem to be a straightforward, linear process, as conceptualized by stage models. As we write words, we also mentally plan, organize, and revise (Sommers, 1980).

Writers use four types of knowledge: topical, audiences, genres, and language (Byrnes, 1996). *Topical knowledge* is needed to generate and organize ideas. *Knowledge of audiences* includes what the writer thinks readers know and want to hear. *Genres* are types of writing (e.g., essays, narrative stories, or poems). *Language* includes vocabulary, grammar, and pragmatics (e.g., how to convey tone or emotion). With development, children become more knowledgeable of each of these types, but equally important, they develop the capability to reflect on and effectively use each type of knowledge while writing.

Contemporary writing models examine writers' mental processes as they engage in different aspects of writing (de Beaugrande, 1984; Byrnes, 1996; Graham, 2006; Mayer,

1999; McCutchen, 2000). A general research goal is to define expertise. By comparing expert writers with novice writers, researchers identify how their mental processes diverge (Bereiter & Scardamalia, 1986). One useful strategy is having writers think aloud (say aloud everything they think about) while writing (Hayes & Flower, 1980). Think-aloud protocols are recorded, transcribed, and analyzed to determine which mental processes are associated with indicators of writing expertise (e.g., writing prizes, high grades in writing courses, or extent of professional writing).

This section discusses composition processes that translate initial ideas into print and reviewing processes that alter learners' original thoughts and writings. These components are not mutually exclusive; writing involves interacting with the environment rather than proceeding through absolute stages. Application 10.4 provides classroom exercises in writing.

APPLICATION 10.4

Writing

Teachers can incorporate planning, transcribing, and revising activities into lessons. If Kathy Stone wanted her third-grade students to write a paragraph describing their summer vacations, she might have students share what they did during the summer. Following this large-group activity, she and the children might jointly develop and edit a paragraph about the teacher's summer vacation. This exercise would emphasize the important elements of a good paragraph and components of the writing process.

Students then could be paired and share orally with each other some things done during the summer. Sharing helps students generate ideas to use in transcribing. Following this activity, children can write their summer activities. For the transcribing, students will use their lists to formulate sentences of a paragraph and share their written products with their partners. Partners will provide feedback about clarity and grammar, after which students revise their paragraphs.

The faculty sponsor of the high-school newspaper can incorporate planning, transcribing, and revising activities into producing the paper each week. When the sponsor meets with the newspaper staff each Monday, the sponsor and the students generate topics to be covered for the next issue and plan the layout (e.g., front page stories, types of human interest articles, sports events to cover during the week, or editorial focus) as well as who will be responsible for each piece. Then the students work with partners throughout the week as they transcribe and revise their articles with input from the sponsor.

Gina Brown works with members of her undergraduate educational psychology class as they write their first research paper. She has each student select a topic, develop a basic outline, and compile a list of possible sources, after which she meets with students individually. Then she has students begin the first draft of the paper, giving more attention to the introduction and conclusion. She meets again with students individually to discuss their first drafts and progress and guides them toward what should be done to complete the finished product.

Composition Processes

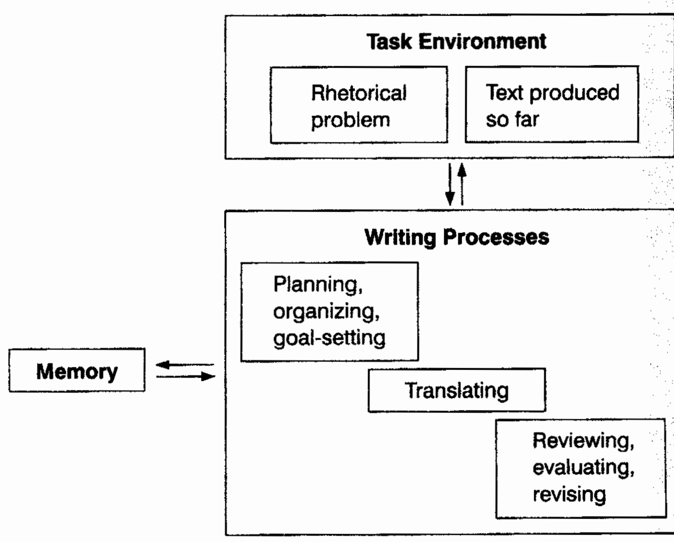
Flower and Hayes (1980, 1981a; Hayes & Flower, 1980) formulated a model that conceptualizes writing as a set of thinking processes that writers organize while composing. Writing is goal-directed behavior; writers generate superordinate and subordinate goals incorporating their purposes and alter their goals based on what they learn while writing. Rather than focus on products of writing, Flower and Hayes emphasized the processes that writers employ throughout writing. The Flower and Hayes model reflects the general problem-solving framework developed by Newell and Simon (1972; Chapter 5). Writers define a problem space and perform operations on their mental representation of the problem to attain their goals (Figure 10.2).

The *rhetorical problem* includes the writer's topic, intended audience, and goals. In classrooms, the rhetorical problem often is well defined; teachers assign a term paper topic, the audience is the teacher, and the goal (e.g., to inform or to persuade) is provided; however, the rhetorical problem is never defined completely by someone other than the writer. Writers interpret problems in their own ways.

The writer's LTM plays a crucial role. Writers differ in their knowledge of the topic, audience, and mechanics of writing (organization, grammar, spelling, and punctuation). Writers knowledgeable about their topics include fewer irrelevant statements in their compositions but more auxiliary statements (designed to elaborate upon main points) compared with less-knowledgeable writers (Voss, Vesonder, & Spilich, 1980). Differences in declarative knowledge affect the quality of writing.

Planning involves forming an internal representation of knowledge to be used in composing. The internal representation generally is more abstract than the actual writing. Planning includes several subprocesses, such as generating ideas by retrieving relevant information from memory or other sources. These ideas may be well formed or fragmentary. Organizing helps give ideas better meaning by grouping them into superordinate and

Figure 10.2
Process model of writing.
Source: Adapted from "A Cognitive Process Theory of Writing," by L. Flower and J. R. Hayes, 1981, *College Composition and Communication, 32*, p. 370. Copyright 1981 by the National Council of Teachers of English. Reprinted with permission.



subordinate roles. Organizing also includes deciding on the flow of the text—what to present first, next, and so forth.

A major subprocess is *goal setting*. Goals are substantive (what the writer wants to communicate) and procedural (how to communicate or how points should be expressed). Good writers often alter their goals based on what they produce. Writers have goals in mind before writing, but as they proceed, they may realize that a certain goal is not relevant to the composition. New goals are suggested by actual writing.

There are wide individual differences in writers' planning skills. The Flower and Hayes model may not be entirely appropriate for children, whose writing typically resembles "knowledge telling" (McCutchen, 1995; Scardamalia & Bereiter, 1982). Children often follow a "retrieve and write" strategy; they access LTM with a cue from the topic or the genre and write down what they know. Relative to the Flower and Hayes model, children do little planning and reviewing and much translating. Whereas older writers also retrieve content from LTM, they do it as part of planning, after which they evaluate its appropriateness before translating. With children, the retrieval and the translation are integrated in seamless fashion (Scardamalia & Bereiter, 1986).

Young children produce fewer ideas than older ones (Scardamalia & Bereiter, 1986). Among older students, higher scores on the critical reading portion of the College Board SAT are associated with greater idea generation (Glynn, Britton, Muth, & Dogan, 1982). Idea generation depends on students' cues to produce more ideas. Younger children benefit from prompting by others (e.g., "Can you write some more?"). Englert, Raphael, Anderson, Anthony, and Stevens (1991) showed that fourth and fifth graders' writing improved when they were exposed to teachers who modeled metacognitive components of the writing process (e.g., which strategies were useful and when and why they were useful) and when they were taught to generate questions during text planning. Older and better writers make greater use of internal prompts. They search relevant topics in LTM and assess knowledge before they begin composing. Teachers can foster idea generation by cueing students to think of ideas and by having them read and save articles on topics to serve as sources of ideas (Bruning et al., 2004).

Organization is conveyed through *cohesion* among sentence parts and coherence across sentences. Cohesive devices tie ideas together with pronouns, definite articles, conjunctions, and word meanings. For example, in the following sentences, the referent of "he" is unclear: "Joe and Jim sat together during the game. He left to get some food." Cohesion is obtained with, "Joe and Jim sat together during the game. Joe left to get some food," or with, "Joe, who sat with Jim during the game, left to get some food." Young children have more difficulty with cohesion, but unskilled writers of any age use cohesion less well. Developmental differences also are found in coherence. Young writers have difficulty linking sentences with one another and with the topic sentence (McCutchen & Perfetti, 1982). Good writers have better coherence than poor writers.

Goals of good and poor writers differ. The primary goal of skilled writers is to communicate meaning. Similar to many children, poor writers often practice *associative writing* (Bereiter, 1980); they put onto paper the contents of LTM relevant to the topic. They may believe the goal of writing is to regurgitate everything they know about the topic; order is less important than inclusiveness. Another goal of less-skilled writers is to avoid making errors. When asked to critique their own writing, good writers focus

on how well they communicated their intentions, whereas poor writers cite surface considerations (e.g., spelling and punctuation) more often.

Translation (Figure 10.2) refers to putting one's ideas into print. For children and inexperienced writers, translating often overburdens WM. They must keep in mind their goal, the ideas they wish to express, and the necessary organization and mechanics. Good writers concern themselves less with surface features during translation; they focus more on meaning and apparently think that they can correct surface problems later. Poor writers concentrate more on surface features and write more slowly than good writers. Better writers take stylistic and surface considerations into account when they pause during writing. Poorer writers benefit when they read what they have written as they prepare to compose.

A common problem in translation is *writer's block* or difficulty in beginning to compose. Block may be caused by inadequate knowledge of the topic or by lack of interest. Rose (1980) found that adopting rigid rules for writing can cause block. For example, writers who believe they must begin an essay with a quote or make three important points in the essay may get stuck when they find that they cannot follow these rules.

The Flower and Hayes model has proven to be remarkably durable and has served as the conceptual framework for much research. Recently, investigators have expanded the model to provide greater clarity (Hayes, 1996; McCutchen, 2000). One key modification postulates a type of LT-WM, which contains elements activated in ST-WM (Chapter 4) and retrieval structures that link items in STM to related elements in LTM. In this view, writing expertise develops as writers more effectively use LT-WM to coordinate elements in LTM and employ them in writing. Novice writers show limitations in both WM and LT-WM, whereas skilled writers not only possess better LTM knowledge but also coordinate its use better during writing (McCutchen, 2000).

Reviewing Processes

Reviewing consists of *evaluating* and *revising*. Reviewing occurs when writers read what they have written as a precursor to further translation or systematic evaluation and revision (Flower & Hayes, 1981a; Hayes & Flower, 1980). During reviewing, writers evaluate and modify plans and alter subsequent writing.

These processes are important because writers may spend as much as 70% of their writing time *pausing* (Flower & Hayes, 1981b), much of which is spent on sentence-level planning. Writers reread what they have written and decide what to say next. These *bottom-up processes* construct a composition a section at a time. When such building up is accomplished with the overall plan in mind, the composition continues to reflect the writers' goals.

Poor writers typically depend on bottom-up writing. While pausing, good writers engage in rhetorical planning not directly linked to what they have produced. This type of planning reflects a *top-down view* of writing as a problem-solving process; writers keep an overall goal in mind and plan how to attain it or decide that they need to alter it. Abstract planning may include information about content (deciding what topic to discuss) and style (deciding to alter the style by inserting an anecdote). This abstract or whole-text planning subsumes sentence-level planning and is characteristic of mature writers (Bereiter & Scardamalia, 1986).

Elementary school children often recognize when their writing contains problems but do little revising without teacher or peer support (Fitzgerald, 1987). Students benefit from instruction designed to improve the quality of their writing. Fitzgerald and Markham (1987) gave average sixth-grade writers instruction on types of revisions: additions, deletions, substitutions, and rearrangements. The teacher explained and modeled each revision strategy, after which students worked in pairs (*peer conferences*). Instruction improved students' knowledge of revision processes and their actual revisions. Beal, Garrod, and Bonitatibus (1990) found that third- and sixth-grade children who were trained to apply a self-questioning strategy (e.g., "What is happening in the story?") located and revised significantly more target text than did nontrained students.

Evaluation skills develop earlier than revision skills. Even when fourth graders recognize writing problems, they may not successfully correct them as often as 70% of the time (Scardamalia & Bereiter, 1983). When children correct problems, differences between good and poor writers become evident. Among fourth- and seventh-grade students, poor writers revise errors in spelling and punctuation, whereas better writers revise for stylistic reasons (Birnbaum, 1982).

Older students also sometimes fail to recognize problems in writing. Among high-school students, good writers revise more than average writers (Stallard, 1974), and a greater proportion of good writers' revisions involves problems in word choice (meaning). Stallard found these two groups did not differ in spelling, punctuation, or other syntactic revisions.

Given the complexity of writing, the course of skill acquisition is better characterized as the development of *fluency* rather than automaticity that is seen in other domains (e.g., reading; McCutchen, 1995). Automatic processes become routinized and require few attentional or WM resources, whereas fluent processes—although rapid and resource efficient—are thoughtful and can be altered "online." Thus, good writers follow plans but revise them as they write. Were these processes automatic, writers' plans—once adopted—would be followed without interruption. Although component skills of writing (i.e., spelling and vocabulary) often become automatic, the overall process does not.

Motivation and Self-Regulation

Like other forms of learning, the development of writing skill is affected by motivation and self-regulation (Graham, 2006). Bruning and Horn (2000) characterized this development as "a highly fluid process of problem solving requiring constant monitoring of progress toward task goals" (p. 25). Hayes's (2000) revised cognitive model of writing incorporates self-regulation. Students are active information processors who employ cognitive and metacognitive strategies during writing.

Goal setting and self-monitoring of goal progress are key self-regulatory and motivational processes (Schunk, 1995). Zimmerman and Kitsantas (1999) found that high schoolers who shifted their goals from process (following steps in a strategy) to outcomes (number of words in sentences) showed higher writing revision skill, self-efficacy, and interest than students who pursued only process or only outcome goals. These results suggest that as skills develop, students can shift their focus from following a strategy to the outcomes that strategy use produces. Although more research is needed on the effects of instructional procedures on motivation to write, writing motivation can be enhanced by

using authentic writing tasks and by creating a supportive context for writing (e.g., the task appears doable with requisite effort).

Klassen (2002) reviewed the literature on self-efficacy for writing. Most studies found that self-efficacy was a significant predictor of writing achievement. Some studies yielded gender differences in self-efficacy with boys' judgments higher than those of girls although there were no performance differences. Establishing a classroom environment that builds self-efficacy is conducive to improving writing.

Writing is demanding and requires attention control, self-monitoring, and volitional control. Graham and Harris (2000) noted that self-regulation affects writing in two ways. For one, self-regulatory processes (e.g., planning, monitoring, and evaluating) provide building blocks that are assembled to complete a writing task. For another, these processes can lead to strategic adjustments in writing and longer-term effects. Thus, successful planning will increase its likelihood of future use and build self-efficacy for writing, which in turn positively impacts motivation and future writing. Teaching students self-regulatory skills in the context of writing assignments results in higher achievement and motivation (Graham & Harris, 2000; Schunk & Swartz, 1993a, 1993b).

The Self-Regulated Strategy Development model discussed in the preceding section has been widely applied to writing (Graham, Harris, MacArthur, & Schwartz, 1998; Harris & Graham, 1996). This model utilizes teacher modeling of writing strategies, collaborative peer group practice, and independent practice, where assistance (scaffolds) are generally faded out. The model has been used successfully with students with writing problems, learning disabilities, and attention deficit/hyperactivity disorders (Harris et al., 2006; Reid & Lienemann, 2006). The model includes general and genre-specific strategies (recall the introductory scenario) as well as motivational components (e.g., self-reinforcement). De La Paz (2005) found that the model helped culturally diverse students improve their argumentative essay writing skills.

Given that writing involves language and reflects one's thoughts and cognitive processes, writing has been viewed as a way to improve learning capabilities and academic achievement. This "writing to learn" idea stresses having students write in various disciplines. Bangert-Drowns, Hurley, and Wilkinson (2004) reviewed the research literature on writing-to-learn interventions and found a small positive effect on overall academic achievement. These researchers also found that prompting students during writing to reflect on their knowledge and learning processes was effective in raising achievement. These findings suggest that writing-to-learn has promise as a useful way to augment content-area learning.

MATHEMATICS

Let us now turn to the content area of *mathematics*, which has been an especially fertile area of cognitive and constructivist research (Ball, Lubienski, & Mewborn, 2001; Schoenfeld, 2006; Voss et al., 1995). Topics that have been explored include how learners construct mathematical knowledge, how experts and novices differ, and which methods of instruction are most effective (Byrnes, 1996; Mayer, 1999; Schoenfeld, 2006). The improvement of mathematics instruction is important given that so many students have difficulty learning mathematics (recall Kim's difficulty with algebra in the opening scenario).

A distinction is typically made between mathematical *computation* (use of rules, procedures, and algorithms) and *concepts* (problem solving and use of strategies). Computational and conceptual problems require students to implement productions involving rules and algorithms. The difference between these two categories lies in how explicitly the problem tells students which operations to perform. The following are computational problems.

- $26 + 42 = ?$
- $5x + 3y = 19$
- $7x - y = 11$
- Solve for x and y.
- What is the length of the hypotenuse of a right triangle with sides equal to 3 and 4 inches?

Although students are not explicitly told what to do in problems 2 and 3, recognition of the problem format and knowledge of procedures lead them to perform the correct operations.

Now contrast those problems with the following:

- Alex has 20 coins composed of dimes and quarters. If the quarters were dimes and the dimes were quarters, he would have 90 cents more than he has now. How much money does Alex have?
- If a passenger train takes twice as long to pass a freight train after it first overtakes the freight train as it takes the two trains to pass when going in opposite directions, how many times faster than the freight train is the passenger train?
- When she hikes, Shana can average 2 mph going uphill and 6 mph going downhill. If she goes uphill and downhill and spends no time at the summit, what will be her average speed for an entire trip?

These word problems use mathematical computations no more difficult than those required by the problems in the first set; however, the latter problems do not explicitly tell students what to do. They must decide how to solve the problems, which involves recognizing their problem formats, generating appropriate productions, and performing the computations.

This is not to suggest that conceptual expertise is better than computational proficiency, although Rittle-Johnson and Alibali (1999) found that conceptual understanding had a greater influence on procedural knowledge than did the reverse. Deficiencies in either area cause problems. Understanding how to solve a problem but not being able to perform the computations results in incorrect answers, as does being computationally proficient but not being able to conceptualize problems. Mathematical proficiency requires learning computation and problem solving together.

Computation Skills

The earliest computational skill children use is *counting* (Byrnes, 1996; Resnick, 1985). Children count objects on their fingers and in their heads using a strategy (Groen & Parkman, 1972). The *sum model* involves setting a hypothetical counter at 0, counting in the first addend in increments of 1, and then counting in the second addend to arrive at the

answer. For the problem "2 + 4 = ?" children might count from 0 to 2 and then count out 4 more. A somewhat more efficient strategy is to set the counter at the first addend (2) and then count in the second addend (4) in increments of 1. Still more efficient is the *min model:* Set the counter at the larger of the two addends (4) and then count in the smaller addend (2) in increments of 1 (Romberg & Carpenter, 1986). Children as young as 4.5 years have been observed to use the min model even though they never have been instructed in its use (Groen & Resnick, 1977).

This type of invented procedure is efficient and successful. Children and adults often construct procedures to solve mathematical problems. Errors generally are not random but rather reflect *buggy algorithms* or systematic mistakes in thinking and reasoning (Brown & Burton, 1978). Buggy algorithms reflect the constructivist assumption that students form procedures based on their interpretation of experiences (Chapter 6). A common mistake in subtraction is to subtract the smaller number from the larger number in each column, regardless of direction, as follows:

$$\begin{array}{r} 53 \\ -27 \\ \hline 34 \end{array} \qquad \begin{array}{r} 602 \\ -274 \\ \hline 472 \end{array}$$

Mathematical bugs probably develop when students encounter new problems and incorrectly generalize productions. In subtraction without regrouping, for example, students subtract the smaller number from the larger one column by column. It is easy to see how they could generalize this procedure to problems requiring regrouping. Rather than ceasing to work problems when they do not know what to do, students modify their rules to fit new problems. Buggy algorithms are durable and can instill in students a false sense of self-efficacy (Chapter 3), perhaps because their computations produce answers.

Another source of computational difficulties is poor declarative knowledge of number facts. Many children do not have basic addition, subtraction, multiplication, and division facts involving simple numbers well established in their memories. The problem "8 × 7 = ?" is a cue to retrieve this fact from LTM. Until facts become established through practice, children count or compute answers. Speed of mathematical fact retrieval from memory relates directly to overall mathematical achievement in students from elementary school through college (Royer, Tronsky, Chan, Jackson, & Marchant, 1999). Children's computational skill improves with development, along with WM and LTM capabilities (Mabbott & Bisanz, 2003).

Many difficulties in computation result from using overly complex but technically correct productions to solve problems. Such procedures produce correct answers, but because they are complex, the risk of computational errors is high. The problem 256 divided by 5 can be solved by the division algorithm or by successively subtracting 5 from 256 and counting the number of subtractions. The latter procedure is technically correct but inefficient and has a high probability of error. One of the goals of computation instruction is for students to become skilled in using efficient procedures.

The development of skill acquisition as discussed in Chapter 4 is relevant to computational skills (Anderson, 1990). Learners initially represent the skill as declarative knowledge in a propositional network. Facts concerning the different steps (e.g., in the algorithm) are committed to memory through mental rehearsal and overt practice. The production that

guides performance at this stage is general, for example, "If the goal is to solve this division problem, they apply the method the teacher taught us."

Learners insert the steps they have memorized into this general heuristic. With added practice, the declarative representation changes into a domain-specific procedural representation and eventually becomes automated. Early counting strategies are replaced with more-efficient rule-based strategies (Hopkins & Lawson, 2002). At the automatic stage, learners quickly recognize the problem pattern (e.g., division problem or square-root problem) and implement the procedure without much conscious deliberation. As a skill develops, learners are able to execute it rapidly and achieve greater accuracy in their answers.

Problem-Solving Skills

Successful mathematical problem solving depends on students possessing knowledge and problem-solving skills. According to Mayer (1989), the most basic type of knowledge involves *resources* or knowledge of basic facts and procedures. A second type of knowledge is of *heuristics* or general strategies for solving problems (Chapter 5). Problem solvers especially need strategies for problem representation and solution planning. Another type of knowledge is *metacognitive* (or *control for monitoring*); it concerns how to manage the problem-solving process. Control is involved in monitoring one's execution of a solution to include discovering errors in computation.

Mathematical problem solving requires that students first accurately represent the problem to include the given information and the goal and then select and apply a problem-solving production (Mayer, 1985, 1999). Translating a problem from its linguistic representation to a mental representation is often difficult.

Formats commonly found in problems given to children include *change problems* (start with a set that increases or decreases because of some action; e.g., Joe has three marbles, Tom gave him five more, how many marbles does Joe have now?); *combine problems* (two sets that do not change but are combined; e.g., Joe has three marbles, Tom has five marbles, how many marbles do they have together?); *compare problems* (two sets that do not change but the difference between them is determined; e.g., Joe has five marbles, Tom has three more marbles than Joe, how many marbles does Tom have? Mayer, 1992). Research shows that children often fail to represent problems correctly and that they are more likely to perform correct computations on incorrect representations. Thus, children may transform one problem type into another (e.g., in the preceding compare example, transform "Tom has more marbles than Joe" into "Joe has more marbles than Tom"). When that happens, an incorrect solution results.

The language used can make even easy word problems difficult (Bruning et al., 2004). The more abstract the language, the more difficult the text comprehension and the lower the likelihood of solution (Cummins, Kintsch, Reusser, & Weimer, 1988). Students who have difficulty comprehending show poorer recall of information and lower performance. This is especially true for younger children, who have difficulty translating abstract linguistic representations.

Translation also requires good declarative and procedural knowledge. Solving the earlier problem about Alex with 20 coins requires knowledge that dimes and quarters are coins, that a dime is one tenth (\$0.10) of \$1, and that a quarter is one fourth (\$0.25) of \$1. This declarative knowledge needs to be coupled with procedural understanding that dimes

and quarters are variables such that the number of dimes plus the number of quarters equals 20.

One reason why experts translate problems better is that their knowledge is better organized in LTM; the organization reflects the underlying structure of the subject matter (Romberg & Carpenter, 1986). Experts overlook surface features of a problem and analyze it in terms of the operations required for solution. Novices are swayed more by surface features.

Silver (1981) asked students to sort mathematical word problems into categories by type and tested their problem-solving skills. Students were classified as good, average, or poor problem solvers. Good problem solvers organized problems according to the process required for solution; poor problem solvers were more likely to group problems with similar content (e.g., money or trains). For example (Mayer, 1982),

> On a ferry trip, the fare for each adult was 50 cents and for each child was 25 cents. The number of passengers was 30 and the total paid was $12.25. How many adults and children were there? (p. 203)

This problem involves two equations with two unknowns. If x = number of adults and y = number of children, then

$$x + y = 30$$
$$0.5\,x + 0.25\,y = 12.25$$

Multiplying the first equation by 0.5 and subtracting the second equation leaves $0.25y = 2.75$ or $y = 11$ children. Substituting the value of y into the first equation yields $x = 19$ adults. Compared with novices, experts are more likely to classify this problem according to solution process (two equations with two unknowns) rather than surface features (money).

In addition to problem translation and classification, experts and novices differ in productions (Greeno, 1980). Novices often adopt a *working backward strategy*, beginning with the goal and working their way back to the givens. Successful use of this strategy requires that problem solvers understand the problem domain sufficiently to realize what knowledge is required to attain each subgoal. Working backward is a good general heuristic useful in the early stages of learning when learners have acquired some domain knowledge but are not competent enough to recognize problem formats quickly. As domain-specific knowledge is learned, more powerful problem-solving productions become available (Anderson, 1990).

In contrast to novices, experts often adopt a *working forward strategy*. They identify the problem type and select the appropriate production to solve the problem. Hegarty, Mayer, and Monk (1995) showed that more- and less-successful problem solvers used different general approaches for understanding word problems. Successful problem solvers used a problem model approach, translating the problem into a mental model in which the numbers in the problem statement were tied to their variable names. By contrast, less-successful solvers were more likely to employ a direct translation approach, combining the numbers in the problem with the arithmetic operations primed by the key words (e.g., addition is the operation linked with the key word "more"). The latter strategy is superficial and based on surface features, whereas the former strategy is linked better with meanings.

Experts develop sophisticated procedural knowledge for classifying mathematical problems according to type. High-school algebra problems fall into roughly 20 general

APPLICATION 10.5
Mathematical Problem Solving

Teachers use various ways to help students improve problem-solving skills. As students solve mathematical word problems, they can state each problem in their own words, draw a sketch, decide what information is relevant, and state the ways they might solve the problem. Kathy Stone could use these and other similar questions to help focus her third-grade students' attention on important task aspects and guide their thinking:

- What information is important?
- What information is missing?
- Which formulas are necessary?
- What is the first thing to do?

categories such as motion, current, coins, and interest/investment (Mayer, 1992). These categories can be aggregated into six major groups. For example, the amount-per-time group includes motion, current, and work problems. These problems are solvable with the general formula: amount = rate × time. The development of mathematical problem-solving expertise depends on being able to classify a problem into the correct group.

As with other skills, classification is developed through teaching and solving different types of problems. Students initially may apply a working backward approach, but with experience, they develop accurate classification procedures. How this novice-to-expert progression occurs is not well understood. Research addressing this progression will have important implications for teaching students to become better problem solvers. Application 10.5 gives some classroom examples of teaching problem solving.

Constructivism

Many theorists contend that constructivism (Chapter 6) represents a viable model for explaining how mathematics is learned (Ball et al., 2001; Cobb, 1994; Lampert, 1990; Resnick, 1989). As with other forms of knowledge, mathematical knowledge is not passively absorbed from the environment but rather is constructed by individuals as a consequence of their interactions. This construction process also includes children's inventing of procedures that incorporate implicit rules.

The following unusual example illustrates this rule-based procedural invention. Some time ago, I was working with a teacher to identify children in her class who might benefit from additional instruction in long division. She named several students and said that Tim also might qualify but she was not sure. Some days he worked his problems correctly, whereas other days his work was incorrect and made no sense. I gave him problems to solve and asked him to verbalize aloud while working because I was interested in what children thought about while they solved problems. This is what Tim said, "The problem is 17 divided into 436. I start on the side of the problem closest to the door. . . ." I then knew why on some days his work was accurate and on other days it was not. It depended on which side of his body was closest to the door!

As noted in Chapter 6, the process of constructing knowledge begins in the preschool years (Resnick, 1989). Geary (1995) distinguished *biologically primary* (biologically based)

from *biologically secondary* (culturally taught) *abilities.* Biologically primary abilities are grounded in neurobiological systems that have evolved in particular ecological and social niches and that serve functions related to survival or reproduction. In humans, these neurocognitive systems can be co-opted for tasks unrelated to their original evolution-based function. Thus, people have evolved neurocognitive systems that are sensitive to features of the three-dimensional physical universe (Shepard, 1994). Consequently, we have developed the capacity to create art in three dimensions. Another example of co-opting may be seen in Euclidean geometry, where the co-optation is of knowledge inherent in understanding of habitat navigation. Map-like environmental representations are used by many species, and the underlying neurocognitive systems seem responsive to Euclidean features of the (three-dimensional) physical universe (Geary, 1995).

Biologically primary abilities should be seen cross-culturally, whereas biologically secondary abilities show greater cultural specificity (e.g., as a function of schooling). Furthermore, many of the former should be seen in very young children. Geary (1995) contended that mathematics-related play may help to develop primary abilities. Play is found across cultures, and preschoolers often engage in play that involves numerical activities such as counting. Indeed, counting is a natural activity that is seen in preschoolers without direct teaching (Gelman & Gallistel, 1978; Resnick, 1985). Even infants may be sensitive to different properties of numbers (Geary, 1995). Preschoolers show increasing numerical competence involving the concepts of part/whole additivity and changes as increases/decreases in quantities.

Conceptual change proceeds quickly during the elementary school years (Resnick, 1989). That children construct mathematical procedures is seen in invented algorithms. Not surprisingly, children have differing amounts of difficulty comprehending story problems. Those easiest to comprehend are those that match their emerging capabilities. "Change" stories are relatively easy, especially when the quantity being asked for is the result of the increase/decrease. The problem is much harder when the unknown is the starting amount (Resnick, 1989), which indicates that children understand part-whole relations. Teaching children to use schematic diagrams to represent story problems facilitates problem solving (Fuson & Willis, 1989).

In addition to biological tendencies and knowledge construction, mathematical competence also depends on sociocultural influence (Cobb, 1994). As discussed in Chapter 6, Vygotsky (1978) stressed the role of competent other persons in the *zone of proximal development* (ZPD). In contrast to the constructivist emphasis on cognitive reorganizations among individual students, sociocultural theorists advocate cultural practices—especially social interactions (Cobb, 1994). The sociocultural influence is incorporated through using activities such as peer teaching, instructional scaffolding, and apprenticeships.

Results of a literature review by Springer, Stanne, and Donovan (1999) showed that small-group learning (2–10 student collaborative/cooperative groups) significantly raised college students' achievement in mathematics and science. Kramarski and Mevarech (2003) found that combining cooperative learning with metacognitive instruction (e.g., reflect on relevant concepts or decide on appropriate strategies to use) raised eighth graders mathematical reasoning more than either procedure alone. In addition to these benefits of cooperative learning (Stein & Carmine, 1999), the literature on peer and cross-age tutoring in mathematics reveals that it is effective in raising performance among White and minority children (Robinson, Schofield, & Steers-Wentzell, 2005). Coordination

of the constructivist and sociocultural perspectives is possible, for example, students develop knowledge through social interactions but then idiosyncratically construct uses of that knowledge.

Individual Differences

Much has been written in recent years on gender and ethnic differences in mathematical achievement (Byrnes, 1996; Halpern, 2006; Meece, 2002). Some evidence shows that boys tend to outperform girls and that Asian Americans and White Americans do better than African Americans and Hispanic Americans; however, the literature is complex, often contradictory, and not subject to easy interpretation.

With respect to gender, male students tend to outperform female students on the mathematics portion of the College Board SAT; a similar result is obtained on the ACT mathematics test. Boys seem to perform better on problem solving if the students either are older than age 14 or are gifted, whereas girls perform better on computations when the students are younger than age 15 and when the test requires knowing whether the students have sufficient information to solve the problems and the students are gifted (Becker, 1990; Byrnes, 1996). Royer et al. (1999) found that among higher-performing students, boys displayed faster mathematical fact retrieval than girls. Nonetheless, girls typically earn better mathematics grades than boys (Meece, 2002). Gender differences favoring boys also have been obtained in other cultures (e.g., Germany; Rustemeyer & Fischer, 2005).

Ethnic differences in mathematical achievement are more consistent and pronounced. Based on several research studies, experts draw the following conclusions (Byrnes, 1996):

- White American students perform better than African-American and Hispanic American students.
- Asian American students perform better than White Americans.
- Researchers find no significant difference in mathematical achievement between African-American and Hispanic American students.

A few caveats are in order. A confounding factor is socioeconomic status (SES); Stevenson, Chen, and Uttal (1990) found that differences between White American, African-American, and Hispanic American students disappeared when SES was taken into account. Regardless of ethnicity, mathematics achievement bears a significant and positive relation to SES. Differences are most pronounced for formal (curriculum-based) mathematics achievement (Byrnes, 1996). Researchers find little evidence for ethnic differences in children's informal (constructed) knowledge. These findings are consistent with Geary's (1995) contention that biologically primary abilities should be evident across cultures, whereas biologically secondary abilities are more susceptible to cultural influence.

Other variables that have been shown to influence mathematical achievement are school transitions, self-regulation, and motivation. Anderman (1998) studied adolescents with learning disabilities and found higher achievement among those who did not make a transition until the ninth grade compared with students who made an earlier transition. School transitions can lead to declines in motivation and achievement (Chapter 8), and they seem especially problematic for students with learning problems.

Mathematics learning can be enhanced by teaching students effective strategies (general and specific). This approach is followed in the self-regulated learning strategies program (Fuchs et al., 2003a; see section on reading). Fuchs et al. worked with third-grade students on mathematical problem solving. Self-regulation strategies included goal setting for individual sessions and self-monitoring and self-assessment of progress toward goal attainment. These general strategies were supplemented with specific strategies to use to solve the problems. Compared with regular teacher instruction, self-regulation instruction increased students' performance and transfer of skills. Other research shows that teaching strategies to children with learning disabilities and those who have experienced difficulties learning mathematical skills improves self-efficacy and achievement (Schunk, 1985; Schunk & Cox, 1986).

Motivational variables (Chapter 11) have been implicated as causes of mathematical performance (Meece, 2002; Schutz, Drogosz, White, & DiStefano, 1998). Among sixth graders, Vermeer, Boekaerts, and Seegers (2000) found that girls reported lower-perceived competence (i.e., self-efficacy) than boys on applied problem solving and were more likely to attribute poor performance to low ability and high task difficulty (attributions to uncontrollable variables). Girls often report lower self-efficacy in mathematics than boys (Rustemeyer & Fischer, 2005) although this gender difference is not consistent (Meece, 2002). Self-efficacy, however, is a strong predictor of mathematics performance (Chen, 2003; Pajares & Schunk, 2001; Pietsch, Walker, & Chapman, 2003). Goal setting (McNeil & Alibali, 2000) and self-efficacy enhancing interventions (Schunk & Ertmer, 2000) are effective for promoting motivation in mathematics.

SCIENCE

We now turn to the fourth content domain: science. Much current research in scientific domains compares novices with experts to identify the components of expertise. Researchers also are investigating students' construction of scientific knowledge and the implicit theories and reasoning processes that students use during activities involving problem solving and learning (Linn & Eylon, 2006; Voss et al., 1995; White, 2001; C. Zimmerman, 2000). We begin by discussing expert–novice differences in knowledge and strategies.

Expert–Novice Differences

Experts in scientific domains differ from novices in quantity and organization of knowledge. Experts possess more domain-specific knowledge and are more likely to organize it in hierarchies, whereas novices often demonstrate little overlap between scientific concepts.

In the Chi et al. (1981) study, novices classified physics problems based on superficial features (e.g., apparatus); experts classified the problems based on the principle needed to solve the problem. Experts and novices also differed in declarative knowledge memory networks. "Inclined plane," for example, was related in novices' memories with descriptive terms such as "mass," "friction," and "length." Experts had these descriptors in their memories but in addition had stored principles of mechanics (e.g., conservation of energy

or Newton's force laws). The experts' greater knowledge (in terms of principles) was organized with descriptors subordinate to principles.

Novices often use principles erroneously to solve problems. McCloskey and Kaiser (1984) posed the following question to college students:

> A train is speeding over a bridge that spans a valley. As the train rolls along, a passenger leans out of a window and drops a rock. Where will it land?

About one third of the students said the rock would fall straight down (Figure 10.3). They believed that an object pushed or thrown acquires a force but that an object being carried by a moving vehicle does not acquire a force, so it drops straight down. The analogy the students made was with a person standing still who drops an object, which falls straight down. The path of descent of the rock from the moving train is, however, parabolic. The idea that objects acquire force is erroneous because objects move in the same direction and at the same speed as their moving carriers. When the rock is dropped, it continues to move forward with the train until the force of gravity pulls it down. Novices overgeneralized their basic knowledge and arrived at an erroneous solution.

Another difference between novices and experts concerns the use of *problem-solving strategies* (Larkin, 1980; Larkin, McDermott, Simon, & Simon, 1980; White & Tisher, 1986). When confronted with scientific problems, novices often use a means-ends analysis, determining the goal of the problem and deciding which formulas might be useful to

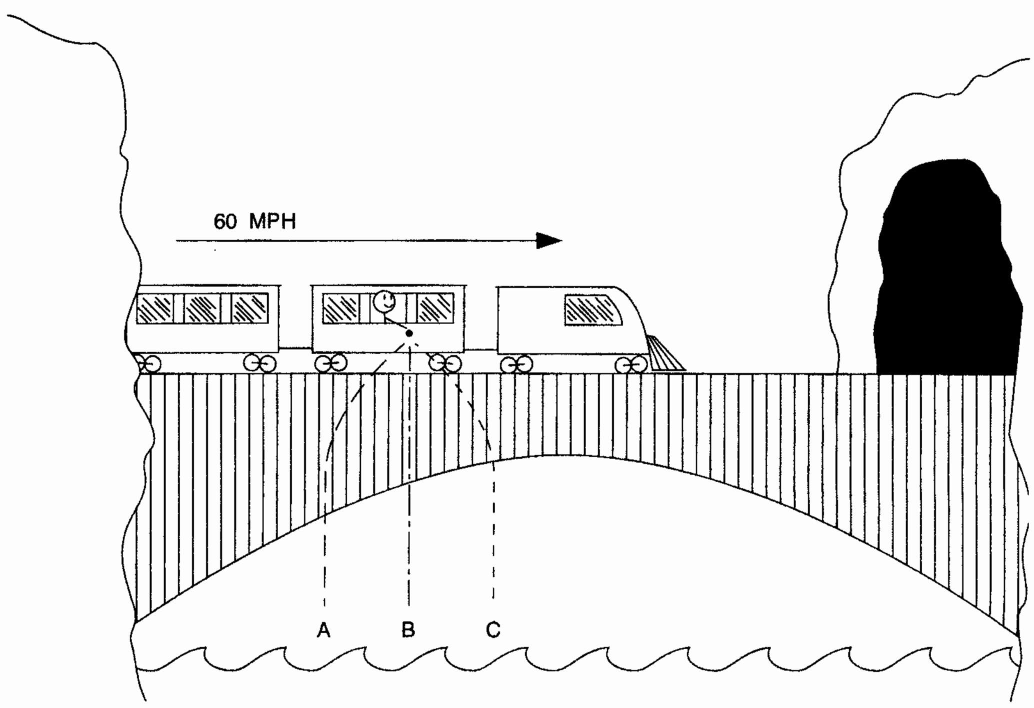


Figure 10.3
Possible answers to falling rock problem.

reach that goal. They work backward and recall formulas containing quantities in the target formula. If they become uncertain how to proceed, they may abandon the problem or attempt to solve it based on their current knowledge.

As is the case in mathematics, experts quickly recognize the problem format, work forward toward intermediate subgoals, and use that information to reach the ultimate goal. Experience in working scientific problems builds knowledge of problem types. Experts often automatically recognize familiar problem features and carry out necessary productions. Even when they are less certain how to solve a problem, experts begin with some information given in the problem and work forward to the solution. Notice that the last step experts take is often novices' first step. Klahr and Simon (1999) contended that the process of scientific discovery is a form of problem solving and that the general heuristic approach is much the same across domains.

Reasoning

Reasoning refers to the mental processes involved in generating and evaluating logical arguments (Anderson, 1990). Reasoning yields a conclusion from thoughts, percepts, and assertions (Johnson-Laird, 1999) and involves working through problems to explain why something happened or what will happen (Hunt, 1989). Reasoning skills include clarification, basis, inference, and evaluation (Ennis, 1987; Quellmalz, 1987; Table 10.1 and Application 10.6).

Clarification. *Clarification* requires identifying and formulating questions, analyzing elements, and defining terms. These skills involve determining which elements in a situation are important, what they mean, and how they are related. At times, scientific questions are posed, but at other times, students must develop questions such as "What is the problem, hypothesis, or thesis?" Clarification corresponds to the representation phase of problem

Table 10.1
Reasoning skills.

Skill	Definition	Sample Questions
Clarification	Identifying and formulating questions, analyzing elements, defining terms	"What do I know?" "What do I need to figure out?"
Basis	Determining source(s) of support for conclusions about a problem	"Is this a fact or opinion?" "What is the source of this information?"
Inference	Reasoning inductively from specific cases to general principles or deductively from general principles to specific cases	"What do these diverse examples have in common?" (induction) "How can I apply these general rules to this example?" (deduction)
Evaluation	Using criteria to judge adequacy of a problem solution	"Do I need more information?" "Is my conclusion reasonable?"

APPLICATION 10.6

Reasoning

Teachers can teach students how to ask questions to produce an accurate mental representation of a problem. A teacher might give primary students objects to classify according to shape. To help students identify and clarify the problem, the teacher could ask questions such as

- What have you been asked to do?
- What items do you have?
- What are some of the shapes you know?
- Does it matter if the items are different colors?
- Does it matter if some of the items are little and some are big?
- Does it matter if some of the items are soft and some are hard?
- What do you think you will do with the items you have?

Students verbalize what information they need to use and what they are supposed to do with that information. Each time the teacher works with students in solving a problem, the teacher can help them generate questions to determine what information is important for solving the problem.

A medical researcher working with a group of interns gives them information about a virus, and their task is to identify the virus. To assist the students in the identification process, the instructor might generate a list of questions similar to the following:

- What effect does the virus have on blood cells?
- What effect does the virus have on human tissue?
- How quickly does the virus appear to grow and under what conditions does it grow?
- What does the virus do when exposed to warmth?
- What does the virus do when exposed to cold?
- What does the virus do when exposed to moisture?
- What does the virus do in an airtight environment?
- What reaction does the virus have when exposed to various drugs?

solving; students define the problem to obtain a clear mental representation. Little productive reasoning occurs without a clear problem statement.

Basis. People's conclusions about a problem are supported by information from personal observations, statements by others, and previous inferences. Judging the credibility of a source is important. In so doing, one must distinguish between fact, opinion, and reasoned judgment. Assume that a suspect armed with a gun is apprehended near the scene of a murder. That the suspect had a gun when arrested is a fact. Laboratory tests on the gun, the bullets, and the victim lead to the reasoned judgment that the gun was used in the crime. Someone investigating the case might be of the opinion that the suspect is the murderer.

Inference. Scientific reasoning proceeds inductively or deductively. *Induction* is the process whereby general rules, principles, and concepts are developed from observation

and knowledge of specific examples (Pellegrino, 1985). It requires determination of a model and its associated rules of inference (Hunt, 1989). People reason inductively when they extract similarities and differences among specific objects and events and arrive at generalizations, which are tested by applying them to new experiences. Individuals retain their generalizations as long as they are effective, and they modify them when they experience conflicting evidence.

Some of the more common types of tasks used to assess inductive reasoning are *classification*, *concept*, and *analogy problems*. Consider the following analogy (Pellegrino, 1985):

> *sugar : sweet :: lemon : _____*
> *yellow sour fruit squeeze tea*

The appropriate mental operations represent a type of production system. Initially, the learner mentally represents critical attributes of each term in the analogy. She activates networks in LTM involving each term, which contain critical attributes of the terms to include subordinate and superordinate concepts. Next, she compares the features of the first pair to determine the link. "Sweet" is a property of sugar that involves taste. She then searches the "lemon" network to determine which of the five features listed corresponds in meaning to "lemon" as "sweet" does to "sugar." Although all five terms are most likely stored in her "lemon" network, only "sour" directly involves taste.

Children begin to display basic inductive reasoning ability around age 8. With development, children can reason faster and with more complex material. This occurs because their LTM networks become more complex and better linked, which in turn reduces the burden on the WM. To help foster inductive thinking, teachers might use a guided discovery approach, in which children learn different examples and try to formulate a general rule. For example, children may collect leaves and formulate some general principles involving stems, veins, sizes, and shapes of leaves from different trees. *Discovery learning* (Bruner, 1960; Chapter 7) can enhance inductive thinking. To use this method, the teacher might pose a problem for students, such as "Why does metal sink in water but metal ships float?" Rather than tell students how to solve the problem, the teacher might provide materials and encourage them to formulate and test hypotheses as they work on the task. Phye (1997) discusses effective teaching methods and programs that have been used to teach inductive reasoning to students.

Deduction is the process of applying inference rules to a formal model of a problem to decide whether specific instances logically follow. When individuals reason deductively, they proceed from general concepts (premises) to specific instances (conclusions) to determine whether the latter follow from the former. A deduction is valid if the premises are true and if the conclusion follows logically from the premises (Johnson-Laird, 1985, 1999).

Linguistic and deductive reasoning processes are intimately linked (Falmagne & Gonsalves, 1995; Polk & Newell, 1995). One type of deduction problem is the *three-term series* (Johnson-Laird, 1972). For example,

> *If Karen is taller than Tina, and*
> *If Mary Beth is not as tall as Tina, then*
> *Who is the tallest?*

The problem-solving processes employed with this problem are similar to those discussed previously. Initially, one forms a mental representation of the problem, such as $K > T$ and $MB < T$. One then works forward by combining the propositions ($K > T > MB$) to solve

the problem. Developmental factors limit children's proficiency in solving such problems. Children may have difficulty keeping relevant problem information in WM and may not understand the language used to express the relationships.

Another type of deductive reasoning problem is the *syllogism.* Syllogisms are characterized by premises and a conclusion containing the words *all, no,* and *some.* The following are sample premises:

All university professors are lazy.
Some graduate students are not lazy.
No undergraduate student is lazy.

A sample syllogism is as follows:

All the students in Ken's class are good in math.
All students who are good in math will attend college.
(Therefore) All the students in Ken's class will attend college.

Researchers debate what mental processes people use to solve syllogisms, including whether people represent the information as Venn (circle) diagrams or as strings of propositions (Johnson-Laird, 1985). A production system analysis of syllogisms gives a basic rule: A syllogism is true only if there is no way to interpret the premises to imply the opposite of the conclusion, that is, a syllogism is true unless an exception to the conclusion can be found. Research needs to examine the types of rules people apply to test whether the premises of a syllogism allow an exception.

Research also is needed on the mechanisms of the deductive reasoning process. Three major views have been proposed (Johnson-Laird, Byrne, & Tabossi, 1989). One view holds that reasoning proceeds on the basis of formal rules of inference. People learn the rules (e.g., the *modus ponens* rule governs "if *p*, then *q*" statements) and then match instances to the rules. A second, related view postulates content-specific rules. They may be expressed as productions such that specific instances trigger the production rules. Thus, a production may involve all cars and may be triggered when a specific car ("my brand X") is encountered.

A third view holds that reasoning depends on semantic procedures that search for interpretations of the premises that are counterexamples to conclusions. According to this view, people construct one or more mental models for the assertions they encounter (interpretations of the premises); the models differ in structure and are used to test the logic of the situation. Students may repeatedly re-encode the problem based on information; thus, deduction largely is a form of verbal reasoning (Polk & Newell, 1995). Johnson-Laird and colleagues (Johnson-Laird, 1999; Johnson-Laird, Byrne, & Schaeken, 1992; Johnson-Laird et al., 1989) have extended this semantic analysis to various classes of inferences (e.g., those involving *if, or, and, not,* and multiple quantifiers). Further research also will help determine instructional implications of these theoretical analyses.

Evaluation. *Evaluation* involves using criteria to judge the adequacy of a problem solution. In evaluating, students address questions such as "Are the data sufficient to solve the problem?" "Do I need more information?" and "Are my conclusions based on facts, opinions, or reasoned judgments?" Evaluation also involves deciding what ought to happen next—that is, formulating hypotheses about future events, assuming that one's problem solving is correct so far.

Deductive reasoning also can be affected by content apart from the logic. Wason (1966) put four cards (A, B, 2, and 3) in front of participants. They were told that each card contained a letter on one side and a number on the other, and they were given a conditional rule: "If a card has A on one side, then it has 2 on the other." Their task was to select the cards that needed to be turned over to determine whether the rule was true. Although most participants picked the A card and many also chose the 2, few picked the 3; however, it must be turned over because if there is an A on the other side, then the rule is false. When the content was changed to an everyday generalization (e.g., letter = hair color, number = eye color, A = blond hair, and 2 = blue eyes), most people made the correct selections (Wason & Johnson-Laird, 1972). These results speak to the importance of not assuming generalization in reasoning but rather giving students experience working on different types of content.

Metacognitive processes enter into all aspects of scientific reasoning. Learners monitor their efforts to ensure that questions are properly posed, that data from adequate sources are available and used to draw inferences, and that relevant criteria are employed in evaluation. Teaching reasoning requires instruction in skills and in metacognitive strategies. Cognitive load (Chapter 7) also seems important. Scientific reasoning is difficult if multiple sources of information must be processed simultaneously, which taxes WM. Carlson, Chandler, and Sweller (2003) found that students' science performance benefited from two procedures designed to reduce cognitive load: diagrams and instructions that minimized the amount of information to be processed at the same time.

Constructivism and Scientific Beliefs

The core concept of constructivism—that knowledge is built by learners rather than simply transmitted among persons—is shared by many researchers and science educators (Driver et al., 1994; Linn & Eylon, 2006). One tradition concerns personal theories and the conceptions of phenomena that students develop during environmental interactions. An interesting issue is how students develop scientific misconceptions. From an instructional perspective, an important task is to help students reorganize their theories by challenging and correcting misconceptions (Sandoval, 1995). A second constructivist tradition focuses on the role of mentors and apprenticeships in the development of scientific knowledge. Other traditions examine how knowledge evolves from the interaction of students' beliefs with classroom instructional practices and from the process of enculturating students into scientific discourse and practices. Finally, many educators are concerned with *scientific literacy*, which, depending on how it is defined, could involve (a) understanding the foundations, current status, and many problems in the life and physical sciences or (b) understanding (and possibly reciting) technical definitions of phenomena (Shamos, 1988).

Recall the earlier discussion of learning as a mental process that involves conceptual change (Chapter 5). Piaget (Chapter 8) postulated that change originates from disequilibrium and modifications of knowledge. From a constructivist perspective, teaching to encourage cognitive conflict (and thereby promote learning) involves providing students with experiences that produce conflict and help them resolve it (Sandoval, 1995; Williams & Tolmie, 2000). Much science instruction focuses on helping students confront and change misconceptions (Mayer, 1999). This might entail having students engage in hands-on activities and work with others (e.g., in discussions) to interpret their experiences through selective questioning (e.g., "Why do you think that?" and "How did you figure that?"). This

approach fits well with the Vygotskian emphasis on social influences on knowledge construction (Chapter 6).

According to Driver et al. (1994):

> Learning science is not a matter of simply extending young people's knowledge of phenomena—a practice perhaps more appropriately called nature study—nor of developing and organizing young people's commonsense reasoning. It requires more than challenging learners' prior ideas through discrepant events. Learning science involves young people entering into a different way of thinking about and explaining the natural world; becoming socialized to a greater or lesser extent into the practices of the scientific community with its particular purposes, ways of seeing, and ways of supporting its knowledge claims. (p. 8)

Before they can become socialized into the discourse practices of the scientific community, students must engage in personal construction and meaning making. The socialization does not require them to abandon common sense reasoning. They still will have these ideas available, which often are effective because many scientific phenomena reflect common sense reasoning. Rather than switch from one theory to another, developing scientific literacy involves knowing what theories are and how they become articulated. This process becomes more refined with development (Byrnes, 1996; Williams & Affleck, 1999).

Nussbaum and Novick (1982) proposed a three-stage model for changing student beliefs:

- Reveal and understand student preconceptions.
- Create conceptual conflict with those conceptions.
- Facilitate the development of new or revised schemata about the phenomena under consideration.

Application 10.7 offers some suggestions for addressing scientific beliefs in the classroom.

APPLICATION 10.7

Altering Scientific Misconceptions

From prior learning, students come to new situations with general and specific knowledge that can interfere with new learning. Particularly in the area of science, other learning may impede progress. Teachers can help students by designing activities that will reveal students' preconceptions, create conceptual conflict with those preconceptions, and facilitate the development of new learning.

As middle-school students begin working for the first time with unknown chemicals, they may become very confused. The science teacher might hold up a beaker that contains a blue-colored liquid and a beaker with a yellow-colored liquid and begin to combine these liquids into a larger container. Owing to prior learning as it relates to color combinations, the students assume the liquid will change to green, but instead the combined liquid turns bright pink. The students are perplexed, and the teacher begins the first lesson on properties of various chemicals and their reactions to being combined with other chemicals.

Finally, the role of *motivation* is important in science learning as in other content areas. Although science has many themes that ought to be interesting, studying science holds little interest for many students. Teaching benefits from hands-on instruction and links to aspects of students' lives. For example, motion can be linked to the path of soccer balls, electricity to CD players, and ecology to natural environments in the community. Enhancing interest in topics also can improve the quality of student learning (Sandoval, 1995). Thus, using illustrations and diagrams helps students to understand scientific concepts (Carlson et al., 2003; Hannus & Hyönä, 1999) although some students may need to be taught how to study illustrations as part of text learning.

SOCIAL STUDIES

The final content domain examined in this chapter is social studies, defined as (Byrnes, 1996):

> The social studies consist of an interrelated set of topics related to the history, environment, economics, lifestyles, and governments of peoples who live in this and other regions of the world. (p. 206)

The social studies typically are viewed as comprising history, geography, civics, and political science; economics, psychology, and sociology also may be included. The boundaries for social studies are rather porous, and in school curricula, social studies typically encompass education for citizenship (Seixas, 2001).

Relative to the other content domains discussed in this chapter, less research has been conducted in social studies; however, that situation is changing as researchers increasingly are conducting studies related to teaching and learning. Given the breadth of the field, no attempt is made here to discuss learning in all disciplines. Interested readers should consult other sources (Armento, 1986; Brophy & Alleman, 1999; Byrnes, 1996; Seixas, 2001; VanSledright & Limón, 2006; Wilson, 2001; Wineburg, 1996). This section discusses history and geography, which are central to the K-12 curriculum.

History

Although many people think of history as learning facts, much more than that is included in its study. Educators want students to know not only what happened but also why it happened, why it was significant, and how it fits into a larger chronology of events. These types of learning require that students be able to (Byrnes, 1996)

- Order events in time.
- Understand causal relations among events.
- Realize that historians do not simply report events but rather interpret them.

Let us consider these in turn.

Learning Processes. The ability to *order events in time* shows a developmental progression. Beginning at approximately age 2, children understand the difference between the past and present; however, children's conception of the past is much different from ours (Friedman, 1990). Given children's brief histories, their pasts are not well differentiated. The distinction between the immediate past and the distant past may be clouded.

By age 6 or 7, children can correctly order seasons and holidays, days of the week, and months of the year (Friedman, 1990). This capability improves with development; thus, attempts to teach history as a timeline to young children may be unsuccessful. Schools typically take this into account by focusing early social studies instruction on understanding of neighborhoods and communities. Systematic history instruction generally does not begin until the fifth grade (Byrnes, 1996).

Children's history learning is aided by hands-on activities such as visits to museums and historic venues. Role playing also is encouraged. For example, Kathy Stone may teach a unit on Abraham Lincoln by having the children read a book and watch a video. After this, children might be assigned parts and put on a class play (in period costumes) about some aspect of Lincoln's life.

Understanding causality is difficult for most students. A common problem is that they tend to simplify causes and attribute outcomes to personal motives and preceding actions, when in fact the causes of most significant historical events are complex. When historical causes are not provided in texts, children often simplify them to simple associations between events.

Chapter 11 discusses *attributions* or perceived causes of actions. Attribution research shows that children's causal thinking before approximately age 7 or 8 is very basic and that they do not distinguish inner qualities well. Thus, children may believe that someone who is smarter may perform better, but they are apt to equate "smartness" with "effort" (i.e., the one who works hard also is smart). Differentiation of attributions begins in the later elementary years and continues through adolescence (Nicholls, 1978, 1979).

Understanding that *historians select and interpret events* also is difficult for children because they tend to believe that one reality exists and that when two persons observe the same event they will report it in the same way (Byrnes, 1996). Full understanding of multiple interpretations may not become evident until college age or later.

To help foster the understanding of different perspectives, teachers might have students write their observations of an event and then read these aloud. Children will see how students reported the same event differently. Byrnes (1996) suggests that children act as judges for a display and their ratings then be compared, which will show how children's ratings of the same display do not agree.

Conceptual Change. As with other domains, students often bring misconceptions to history learning. These misconceptions serve as a core through which new information is filtered. For example, Sinatra, Beck, and McKeown (1992) interviewed fifth graders to determine what they understood about history. Even after a year of instruction, students demonstrated poor understanding of significant events. The majority of students did not link the American Revolution with Great Britain. Students' historical knowledge often was intertwined with other significant events (e.g., the Declaration of Independence linked with the freeing of slaves).

Conceptual change also requires that students be taught to use effective problem-solving strategies. Wineburg (1996) reported that historians use three strategies to evaluate historical documents:

- *Corroboration:* Comparing details of a document to others.
- *Contextualization:* Situating events in the document in concrete contexts.
- *Sourcing:* Evaluating the authors of a document for their fairness and accuracy before analyzing the document.

These strategies are used infrequently by high-school students. Even older students view documents as a form of conveying information that should be added to their current knowledge. In short, students' trust of historical documents results in their integrating new information with their existing knowledge.

This type of expert–novice research is illuminating and suggests that teachers can work with students to teach skills of historical analysis. Researchers have shown that having students critically question historical material can foster conceptual change (Armento, 1986; Wineburg, 1996). Application 10.8 offers some applications of history and geography learning in classrooms.

Geography

Geography can cover many types of skills, including map reading and interpretation, identifying major landforms and bodies of water, and locating major cultural regions, political groups, and natural resources (Farrell & Cirrincione, 1989). Map skills lie at the heart of geography education, and they are useful in other disciplines (Liben, Kastens, & Stevenson, 2002). Locations also are important in geography. These are addressed in turn.

Map Skills. Proficiency in map reading requires competence in several subskills including (Byrnes, 1996):

- Recognizing and differentiating among symbols used in maps.
- Understanding that these symbols have three-dimensional counterparts in real life.
- Projecting the spatial arrangements of map symbols onto the physical world.
- Using maps even when they are not aligned with the user's perspective.

By the time children enter kindergarten, they possess some basic map reading skills. For example, if given a map of a room with the location of an object shown on it, most

APPLICATION 10.8
History and Geography

A way to assist students with analyzing historical information is to have them compare various sources. Jim Marshall might have his ninth-grade U.S. history students take a famous speech given by a president or member of Congress and relate it to the actual events taking place at that time. The students have an opportunity then to analyze the contents of the speech and determine whether the facts were accurate. This helps students in evaluating the document.

Geography skills are often learned best if teachers go beyond just locating specific items on maps to relating map skills to another subject area or to a meaningful task. Kathy Stone asks each student in her third-grade class to pick a state (other than the one they live in) that they believe could attract new residents because of the geographic attributes of that state. Then she asks students to create a poster depicting the most important attributes of that state. Somewhere on the poster students will put a map of the state they selected.

children are able to locate the object in the room. They have greater difficulty if they are shown the object in the room and asked to indicate its location on the map. Maps rotated away from children's perspective also cause difficulty in interpretation. These skills develop during the elementary years (Byrnes, 1996; Liben et al., 2002).

In part, this skill acquisition is aided by the development of children's spatial abilities (Liben & Downs, 1993). Children's early experience with map reading can assist skill learning. Using realistic symbols on maps (e.g., a square rather than a dot to represent a building) is helpful, along with giving children practice in mentally rotating maps. Verdi and Kulhavy (2002) summarized research showing that map features along the edge or on interior lines are learned better than those elsewhere in the interior and that viewing a map before reading a text leads to better learning than the reverse order. Proper map construction and sequencing of instruction can play critical roles in geography learning.

Identifying Locations. Much has been written about the poor geography identification knowledge of school children despite the fact that teachers consider such knowledge important. Youngsters in the United States have fared badly on tests assessing knowledge of locations of countries (U.S. Department of Education, 1990). Although location knowledge improves with schooling, even college students are remarkably uninformed about locations.

Using imagery is an effective means of assisting location skills (Chapter 4). For example, teachers can link countries with particular shapes and ask children to imagine those shapes (e.g., Italy in the shape of a boot). The section in Chapter 5 on self-regulation discusses memory strategies, and many of these are helpful. Acronyms and initialisms can be used; thus, the west-to-east configuration of Norway–Sweden–Finland can be remembered with the initialism "NSF," which also stands for "National Science Foundation."

Another way to improve learning of locations is to integrate geography with other content areas, especially history. For example, Switzerland's location between the major powers of World War II (e.g., Germany and Italy) is easy to remember when this knowledge is linked with information about its neutrality in that war. Similarly, Panama's location can be remembered when students understand that this is the narrowest land mass between the Atlantic and Pacific Oceans.

SUMMARY

Developing competence within an academic domain requires a strong knowledge of the facts, principles, and concepts of that domain, coupled with generic learning strategies that can be applied across domains and specific learning strategies that pertain to each domain. Research reveals many differences between experts and novices. Experts possess more domain-specific knowledge organized to reflect the underlying structure of the content. Experts form a more accurate problem representation and usually work forward from the givens to reach the goal. Novices often adopt a working backward strategy. Experts and novices do not seem to differ in their knowledge of problem-solving strategies.

Language comprehension requires perception, parsing, and utilization. People parse language in ways that reflect their deep mental structures. They construct a context and fill in the elements as they comprehend them. Experts have more fully developed mental representations of situations. Utilization requires listeners to determine the function of the

communication: to inform, to request, to command, and so forth. Speakers and listeners may operate according to a given-new contract.

Reading involves decoding and comprehension. Decoding proceeds in top-down and bottom-up fashion. Novices use much bottom-up processing, but as skill develops, learners construct a mental representation of the context and develop expectations about what will appear in print. Experts rely on top-down processing, much of which occurs automatically. Text is comprehended when it activates meanings in LTM. Inferential comprehension is aided when schemata are activated and learners implement productions to fill in slots with information acquired from text. Metacognitive processes assist students' comprehension. Strategy instruction helps students learn to monitor their text understanding.

Writing requires composition and reviewing. Expert writers plan text around a goal of communicating meaning. They generate more ideas and link them better than novices. Experts also keep their goal in mind during reviewing. Novices write by putting down what they can recall about a topic. They focus on what to write next rather than keeping their goal in mind. Although components of writing may become automatic, writing proficiency requires thoughtful consideration of goals, translation, and revising.

Children display early mathematical competence with counting. Computational skills require algorithms and declarative knowledge; deficient procedural or declarative knowledge leads to computational difficulties. Students often overgeneralize procedures, which result in buggy algorithms. In problem solving, students acquire knowledge of problem types through task experience. Experts readily recognize the problem type and apply the appropriate production to solve the problem. They work forward through the solution. Novices work backward by applying formulas that include quantities given in the problem. The sciences involve similar strategies. In mathematics and science, learners seem to construct a great deal of their knowledge based on their environmental interactions. A key skill in reasoning is drawing inferences. Expertise in induction and deduction reflects the application of rule-based productions.

The social studies are composed of a diverse set of content areas, including history, geography, civics, political science, economics, psychology, and sociology. History learning requires developing knowledge about what happened, why it happened, and why it was significant. History subskills include ordering events in time, understanding causality, and realizing that historians interpret events as they report them. These skills improve with development, and effective teaching incorporates role playing and hands-on activities. Geography includes map reading and knowledge of locations. Students must be able to recognize symbols, understand that these correspond to physical reality, and realign themselves with a map's perspective. Spatial ability is critical, but teachers can aid learning by having students use imagery and strategies and by integrating geography across the curriculum.

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