Supplementary Reading #8

LEARNING IN THE CONTENT AREAS

• CASE STUDY: THE BIRTH OF A NATION

• APPLYING GENERAL PRINCIPLES TO TEACHING CLASSROOM SUBJECT MATTER

• READING
  Emergent Literacy • The Nature of Skilled Reading • Developmental Changes in Reading • General Strategies for Teaching Reading

• WRITING
  The Nature of Skilled Writing • Writing as a Facilitator of Learning • Developmental Changes in Writing • General Strategies for Teaching Writing

• MATHEMATICS
  The Nature of Mathematical Reasoning • Developmental Changes in Mathematical Understanding • General Strategies for Teaching Mathematics

• SCIENCE
  The Nature of Scientific Reasoning • Developmental Changes in Scientific Reasoning • General Strategies for Teaching Science

• SOCIAL STUDIES
  The Nature of Historical Knowledge and Thinking • The Nature of Geographic Knowledge and Thinking • Developmental Changes in Thinking About History and Geography • General Strategies for Teaching Social Studies

• TAKING STUDENT DIVERSITY INTO ACCOUNT
  Accommodating Students with Special Needs

• THE BIG PICTURE
  Reading • Writing • Mathematics • Science • Social Studies • Revisiting the Five General Principles

• CASE STUDY: ALL CHARGED UP

• USING THE STUDENT ARTIFACT LIBRARY

What subjects have you especially enjoyed studying in your many years as a student? Do you enjoy classroom topics more when your teachers present them as ideas to be understood, applied, and critically analyzed, rather than just as facts and procedures to be memorized?

When I went to school in the 1950s and 1960s, the general public, as well as many teachers and educational theorists, thought that classroom instruction should be largely a process of teaching specific facts and procedures. But in recent years, theorists and practitioners alike have radically changed their thinking about how school subject matter can most effectively be taught. Although students continue to learn facts and procedures, classroom curricula increasingly focus on helping students develop higher-level thinking skills (transfer, problem solving, critical thinking, metacognitive strategies, etc.) as well (Alleman & Brophy, 1997; Glynn, Yeany, & Britton, 1991; Lester, Lambdin, & Preston, 1997; Newmann, 1997).

In this supplementary reading, we will apply principles of cognition, knowledge construction, and higher-level thinking to learning and instruction in five areas: reading, writing, mathematics, science, and social studies. As we do so, we will consider questions such as these:

1 This reading is an updated version of Chapter 9 in the third edition of Educational Psychology: Developing Learners. It was omitted from the fourth edition to make room for expanded discussions of motivation and assessment.
• What general principles seem to hold true regardless of the subject matter we are teaching?
• How do students’ reading skills change across the school years, and how can we encourage students at various grade levels to read more effectively?
• What specific processes are involved in writing, and how can we help students develop these processes?
• How can we promote a true understanding and application of mathematics, rather than meaningless memorization of mathematical facts and procedures?
• How can we foster scientific reasoning skills, so that students apply scientific concepts and principles to address real-world problems?
• How can we encourage students to use the things they learn in social studies—in particular, in history and geography—to understand and interpret the societies and cultures in which they live?
• What things should we keep in mind when we teach various content areas to students from diverse populations?

Case Study: The Birth of a Nation

Ms. Jackson has asked her second graders to write an answer to this question: The land we live on has been here for a very long time, but the United States has only been a country for a little more than 200 years. How did the United States become a country? Following are some of the children’s responses:

Bill: The United States began around two hundred years ago, when an Inglish ship from Ingland accadently landed on a big State that wasn’t named yet. They named it America, but they didn’t know there was already Indians ashore. Soon they found out, and they had a big fight. The Indians trying to fight the Inglish off, and the Inglish trying to fight off the Indians. So finally they talked and after they worked out their problems then they had a big feast for friendship and relationship.

Matt: It all staredid in eginggind they had a wore. Thein they mad a bet howevry won the wore got a ney country. Called the united states of amarica and amaricins won the wore. So they got a new country.

Sue: The pilgrums we’re sailing to some place and a stome came and pushed them off track and they landed we’re Amaraca is now and made friends with the indens and coled that spot AMARACA!

Lisa: We won the saver wore. It was a wore for fradam and labrt. One cind of labraty is tho stashow of labrt. We got the stashew of labraty from england. Crastaver calbes daskaved Amaraca.2

Meg: The United States began around two hundred years ago. The dinosors hav ben around for six taosine years ago. Christfer klumbis salde the May flowr.


(responses courtesy of Dinah Jackson)

• What writing skills have all of the second graders mastered? What skills are most of them still developing? In what ways are all of these compositions very different from something a high school student might write?

2 This student’s spelling is sufficiently “creative” that a translation is probably in order: “We won the Civil War. It was a war for freedom and liberty. One kind of liberty is the Statue of Liberty. We got the Statue of Liberty from England. Christopher Columbus discovered America.”
• What things have the second graders learned about American history? What misconceptions do you see in their responses? In what ways does their knowledge of history fall short of a true understanding of the birth of the United States?

Applying General Principles to Teaching Classroom Subject Matter

These second graders clearly have a basic understanding of the nature of written language. For instance, they know that, at least in English, writing proceeds from left to right and from the top of the page to the bottom. They are aware that written language should follow certain conventions regarding capitalization and punctuation. They have mastered the spellings of many simple words. They know, too, that how a word is spelled is, at least in part, a function of how it is pronounced—in other words, that different letters correspond to different sounds. For example, when Lisa spells "liberty" as "labrt," she is probably thinking that her word would be pronounced "LAB R T."

At the same time, the children do not yet know how to spell many words, and they are still learning the situations in which capitalization and punctuation are and are not appropriate. For instance, Matt spells "England" as "eginggind" and puts a period in the middle of what should be a sentence. Furthermore, most of the compositions consist of short, choppy sentences that are strung together like beads; only Bill’s response comes close to telling a story. By the time these students reach high school, most of them should be writing multiple-paragraph compositions that have few spelling and punctuation errors and depict a logical sequence of events.

The children have also learned a few things about American history. They know that Columbus sailed across the ocean, that people from England (the Pilgrims) were early settlers who found Native Americans already living on the land, and that George Washington was a prominent figure when the country was formed. But they don’t always have their facts straight. For example, the American Revolution did not involve making a bet, Columbus did not sail on the Mayflower, and George Washington did not “give” us the country. In general, the children’s knowledge of American history consists of only a few isolated pieces of information; they have little or no understanding of how the country actually came into being.

Like Ms. Jackson’s assignment, many classroom tasks involve both language skills, such as reading or writing, and knowledge in one or more academic disciplines, such as mathematics, science, or social studies. As we explore how students learn and achieve in reading, writing, math, science, and social studies, we will repeatedly run into the concepts and principles of learning and development presented in the textbook. But there are several general principles that will feature prominently in our upcoming discussions:

• **Constructive processes.** Learners use the information they receive from various sources to build their own, unique understandings of the world.

• **Influence of prior knowledge.** Learners’ interpretations of new information and events are influenced by what they already know and believe about the world.

• **Role of metacognition.** Over time, learners develop cognitive strategies and epistemological beliefs that influence their thinking and performance within a particular content domain.

• **Qualitative changes with development.** The ways in which learners think about and understand academic subject matter are qualitatively different at different points in their cognitive development.

• **Importance of social interaction.** Learners often gain greater understanding and greater metacognitive sophistication in a subject area when they work collaboratively with their peers.
We see two of these principles—constructive processes and prior knowledge—at work in the second graders’ history compositions. For instance, Lisa uses her knowledge of letter sounds to construct what is, to her, a reasonable spelling of *liberty*, and Meg knows that someone sailed on the *Mayflower* and assumes (incorrectly) that the sailor must have been Columbus. As Lisa and Meg move to higher grade levels, they will construct more accurate and abstract understandings of historical events, express their thoughts on paper more thoroughly and completely, and have greater metacognitive awareness of what they are doing as they write. Furthermore, their success in learning history and other content areas will increasingly depend on their ability to learn through reading textbooks and other printed materials. Accordingly, virtually *all* teachers should teach reading to some extent, even if they are teaching courses in mathematics, science, social studies, or some other discipline.

**Reading**

As a topic of instruction per se, reading is taught primarily in elementary school. Many middle school and high school teachers assume that their students have achieved sufficient reading proficiency to learn successfully from textbooks and other printed materials. Such an assumption is not always warranted, however; even at the high school level, many students have not yet mastered some of the skills they need to read effectively.

In this section we will examine the many skills that contribute to reading ability and consider how the quality of students’ reading changes over time. We will also identify teaching strategies that researchers and practitioners recommend for enhancing students’ ability to read and learn from written language. But first, let’s look at the things that many children learn about reading and writing long before they enter school—knowledge and skills that are collectively known as *emergent literacy*.

**Emergent Literacy**

When you were a young child, perhaps 3 or 4 years old, you may have spent many hours listening to parents or other adults read you storybooks. What might you have learned about the nature of written language from these storybook sessions?

Researchers have consistently found that children who are read to frequently during the preschool years, and especially children who associate reading with pleasure and enjoyment, learn to read more easily once they reach kindergarten and first grade (Baker, Scher, & Mackler, 1997; Crain-Thoreson & Dale, 1992; Frijters, Barron, & Brunello, 2000; Whitehurst et al., 1994). Through storybook reading and other home activities that focus on either oral or written language (storytelling, object and picture identification, practice with the alphabet, rhyming games, etc.), children acquire considerable knowledge and skills essential to the reading process. For instance, they learn that

- Reading proceeds from left to right and from the top of the page to the bottom
- Spoken language is represented in a consistent fashion in written language
- Each letter of the alphabet is associated with one or more sounds in spoken language

They may also learn to recognize their own name in print, and many children begin to recognize the logos of popular products and commercial establishments, such as Coke, Pepsi, McDonalds, and Burger King. Taken together, such knowledge and skills lay a foundation for reading and writing—a foundation that theorists call *emergent literacy*. 
The Nature of Skilled Reading

Reading is a complex process that involves considerable knowledge and abilities:

- Recognizing individual sounds and letters
- Using word decoding skills
- Recognizing most words quickly and automatically
- Using context clues to facilitate word recognition
- Constructing an understanding of the writer’s intended meaning
- Metacognitively regulating the reading process

Sound and Letter Recognition

A growing body of research indicates that **phonological awareness**—hearing distinct sounds, or phonemes, within a spoken word (e.g., detecting the sounds “guh,” “ay,” and “tuh” in the word *gate*)—is an essential element of successful reading. Children who have trouble identifying the specific phonemes contained in words have more difficulty reading than their classmates. Furthermore, specifically teaching students to hear the individual sounds in words enhances later reading ability (Bus & van IJzendoorn, 1999; Byrne, Fielding-Barnsley, & Ashley, 2000; M. Harris & Hatano, 1999; Torgesen et al., 1999). We can use strategies such as the following to promote students’ phonological awareness:

- Ask students to identify objects that all begin with the same sound.
- Show pictures of several objects and ask students to choose the one that begins with a different sound from the others.
- Say several words and ask students which one ends in a different sound.
- Ask students to sound out and blend separate letters into words.
- Play rhyming games. (Bradley & Bryant, 1991; Goswami, 1998; Walton, Walton, & Felton, 2001)

Obviously, another prerequisite for learning to read is learning to distinguish individual letters of the alphabet in uppercase and lowercase forms (Adams, 1990; M. Harris & Giannouli, 1999; W. Schneider, Roth, & Ennemoser, 2000). Although some students will already have learned the written alphabet before they begin school, others may know few if any letters. Especially when we are teaching at the kindergarten or early elementary grade levels, one of our first orders of business must be to determine whether our students have mastered the upper- and lowercase alphabets. Before they begin reading in earnest, our students should be able to identify every letter of the alphabet quickly and effortlessly and associate each letter with one or more sounds that it “makes” in spoken language. To help students learn to recognize letters and their corresponding sounds, we can

- Read alphabet books that embed individual letters in colorful pictures and meaningful stories
- Ask students to make letters with their bodies (e.g., a single student stands with arms outstretched like a Y, or two students bend over and clasp hands to form an M)
- Have students practice writing the letters, first by copying them and eventually by retrieving their forms from memory

Word Decoding Skills

When people see a word for the first time, they often engage in **word decoding**: They identify the sounds associated with the word’s letters and blend those sounds together to determine what the
word probably is. To do this, they must, of course, know how particular letters and letter combinations are typically pronounced. Decoding skills are especially important in the early elementary grades, when students have not yet acquired a large sight-reading vocabulary—in other words, when they cannot yet recognize most words quickly and automatically (Gough & Wren, 1998; Tunmer & Chapman, 1998).

Following are examples of how we can promote word decoding skills:

- Teach generalizations that apply most of the time (e.g., an e at the end of a word is usually silent).
- Show patterns in similarly spelled and pronounced words (e.g., the end in bend, mend, and fender).
- Have students create nonsense words and poems using common letter combinations (e.g., I know an old lady who swallowed a zwing, I don’t why she swallowed the zwing, I guess she’ll die; Reutzel & Cooter, 1999, p. 146).
- Give students lots of practice sounding out unfamiliar words.
- Teach students how to spell the words they are learning to read. (Adams, 1990; Ehri, 1998; Ehri & Wilce, 1987; Reutzel & Cooter, 1999)

Automatic Word Recognition

Try this simple exercise.

EXPERIENCING FIRSTHAND  An Excerpt from Webster’s Dictionary

Read this sentence as quickly as you can while also trying to make as much sense of it as you can (Webster’s Ninth, 1991):

A zymogram is an electrophoretic strip or a representation of it exhibiting the pattern of separated proteins or protein components after electrophoresis.

Did you find yourself slowing down at certain points in the sentence? If so, what particular words slowed you down?

I am guessing that three words slowed you down: zymogram, electrophoretic, and electrophoresis. Unless you are a biologist, you had probably never encountered these words before. But I suspect that you read the other words—even representation, which has fourteen letters—with virtually no effort because you’ve read each of them on many previous occasions.

When students must use their limited working memory capacity to decode and interpret individual words, they have little “room” left to understand the overall meaning of what they are reading. It
is essential, then, that our students develop automaticity in word recognition. Ultimately, word recognition must become automatic in two ways. First, students must be able to sight-read words: They must be able to identify them in a split second, without having to decode them letter by letter. Second, they must be able to retrieve the meanings of words immediately—for example, to know without hesitation what *pattern* and *protein* mean when those words appear in a sentence (Adams, 1990; Hall, 1989; Stanovich, 2000).

As you may recall from Chapter 6 in the textbook, automaticity develops primarily through practice, practice, and more practice. In some instances—perhaps with young children or with students who are having unusual difficulty learning to read—we might use flashcards with individual words. And we can certainly teach the meanings of words through explicit vocabulary lessons. But probably most effective (and certainly more motivating) for promoting automatic word recognition is to encourage students to read as frequently as they possibly can.

**Context Clues**

Here is another exercise to try.

**EXPERIENCING FIRSTHAND**  *A Sense of Urgency*

What is the blurry word in the following sentence?

Even when people have learned words to a level of automaticity, they recognize the words faster and more easily when they see them within the context of a sentence than when they see them in isolation (West & Stanovich, 1978). Probably both the syntax and the overall meaning of the sentence provide context clues that help. For instance, when you read the sentence in the exercise just now, you undoubtedly concluded that the blurry word toward the end must be a noun (only a noun would be syntactically correct between *the* and *on*) and that the noun in question must be something that people attend and something for which punctuality is important. These clues, plus the general length and shape of the word, should have led you to identify the blurry word as *meeting*.

Effective use of context clues seems to be especially important for beginning readers and for those older readers who have not fully developed automaticity in word recognition (Goldsmith-Phillips, 1989; Stanovich, 2000; West & Stanovich, 1978). As teachers, we must remember that the English language isn’t completely dependable when it comes to letter-sound correspondences; for example, the letters *ough* are pronounced differently in *through*, *though*, *bough*, and *rough*. Accordingly, we should encourage students to use context clues as well as letter-sound correspondences whenever they encounter a word they don’t know, perhaps simply by posing the question, “What do you know about the word just by looking at the words around it?”

**Meaning Construction**

Most reading theorists today believe that reading is very much a constructive process (e.g., E. H. Hiebert & Raphael, 1996; C. A. Weaver & Kintsch, 1991). When people read, they usually go beyond the words themselves: They identify main ideas, draw inferences, make predictions about what the author is likely to say next, and so on. Sophisticated readers may also find symbolism in a
work of fiction, evaluate the quality of evidence in a persuasive essay, or identify assumptions or philosophical perspectives that underlie a particular piece of writing.

Effective meaning construction in reading is, of course, enhanced by the amount of knowledge that the reader already has about the topic in question (Beck, McKeown, Sinatra, & Loxterman, 1991; Britton, Stimson, Stennett, & Gülgöz, 1998). For instance, if you were a biologist who knew what electrophoretic and electrophoresis were, then you would have little difficulty comprehending the zymogram definition I gave you earlier. Similarly, second graders who already know a lot about spiders remember more when they read a passage about spiders and can draw inferences more readily than their less knowledgeable classmates (Pearson, Hansen, & Gordon, 1979). Helpful, too, is knowledge about the structures that various types of literature typically follow; for example, the events described in works of fiction usually follow a chronological sequence, and persuasive essays usually begin with a main point and then present evidence to support that point (Byrnes, 1996; Dryden & Jefferson, 1994; Graesser, Golding, & Long, 1991; Mandler, 1987).

Following are several suggestions that experts have offered for helping students construct meaning from the things they read:

- Remind students of the things they already know about the topic.
- Give students specific training in drawing inferences from reading material.
- Relate events in a story to students’ own lives.
- Ask students to form mental images of the people or events depicted in a reading passage.
- Ask students to retell or summarize what they have read, perhaps after each sentence, paragraph, or section. (Chi, de Leeuw, Chiu, & LaVancher, 1994; Gambrell & Bales, 1986; Hemphill & Snow, 1996; Johnson-Glenberg, 2000; Morrow, 1989; Oakhill & Yuill, 1996; Pressley, El-Dinary, Wharton-McDonald, & Brown, 1998)

Metacognitive Processes

Not only do good readers work actively to construct meaning from what they read, they also “supervise” their own reading at a metacognitive level. Many of the metacognitive strategies identified in Chapter 8 of the textbook—for instance, elaborating, summarizing, and comprehension monitoring—are particularly important in reading. Good readers also spend more time on parts of a passage that are likely to be critical to their overall understanding, and they frequently make predictions about what they will read next (Gernsbacher, 1994; Hyona, 1994; Palincsar & Brown, 1984). Furthermore, good readers typically set goals for their reading; for example, they may ask themselves questions that they hope to answer as they read (Hall, 1989; Webb & Palincsar, 1996).

The textbook identifies several ways of promoting effective metacognitive strategies, and many of them are certainly applicable to teaching reading. We can further encourage metacognitive processing by explicitly teaching students to use the kinds of strategies that good readers use; for instance, we can teach them to summarize what they read by deleting trivial and redundant information and identifying general ideas that incorporate several more specific ideas (Bean & Steenwyk, 1984). We can also teach them to make predictions as they read—perhaps by looking at the title and section headings, and perhaps by considering the ideas that have already been presented—and then to reflect back on the accuracy of their predictions (Pressley et al., 1994). Group discussions of reading material provide yet another way of enhancing students’ metacognitive skills; I describe some techniques along this line later in this section, as well as in the discussion of reciprocal teaching in Chapter 13 of the textbook.
Developmental Changes in Reading

As students grow older and gain more experience as readers, their reading processes and skills improve in several ways. A major accomplishment during the kindergarten and early elementary grades is the development of phonological awareness; by second grade, most students are able to divide words into syllables and into the specific phonemes that make up each syllable (Lonigan, Burgess, Anthony, & Barker, 1998; R. E. Owens, 1996). Reading instruction in the early elementary years typically focuses on word recognition and basic comprehension skills, often within the context of reading simple stories (Chall, 1996; R. E. Owens, 1996).

In the upper elementary grades, most students have acquired sufficient linguistic knowledge and reading skills that they can focus almost exclusively on reading comprehension (R. E. Owens, 1996). They are more adept at drawing inferences, and they become increasingly able to learn new information from what they read (Chall, 1996; Paris & Upton, 1976). At this point, they tend to take the things they read at face value, with little attempt to evaluate them critically and little sensitivity to obvious contradictions (Chall, 1996; Johnston & Afflerbach, 1985; Markman, 1979).

As students move into the secondary grades, they become more skillful at identifying main ideas, summarizing passages of text, monitoring their comprehension, and backtracking when they don’t understand something the first time they read it (Alvermann & Moore, 1991; Byrnes, 1996; Garner, 1987). They also begin to recognize that different authors sometimes present different viewpoints on a single issue, and they read written material with a critical eye instead of accepting it as absolute truth (Chall, 1996; R. E. Owens, 1996). Furthermore, they become more cognizant of the subtle aspects of fiction, such as the underlying theme and symbolism of a novel (Chall, 1996). We must keep in mind, however, that students’ general knowledge of the world and their experiences with a variety of both fictional and nonfictional literature will definitely have an impact on their ability to read challenging material successfully (Byrnes, 1996).

General Strategies for Teaching Reading

As we identified the various processes involved in effective reading, we also identified instructional strategies that should promote the development of those processes. Following are several more general strategies to keep in mind:

- **Make frequent use of authentic reading materials, and give students some choices about what they read.** Chapter 8 in the textbook notes the importance of using authentic activities for promoting real-world transfer of the knowledge and skills that students learn in the classroom. Many reading theorists advocate the frequent use of authentic reading materials as well—having students read storybooks, novels, magazine articles, newspaper articles, poems, and so on—rather than a heavy reliance on the traditional “reading” textbooks so common in the 1970s and 1980s. Furthermore, research consistently tells us that students read more energetically and persistently, use more sophisticated metacognitive strategies, and remember more content when they are interested in what they are reading (R. C. Anderson, Shirey, Wilson, & Fielding, 1987; J. T. Guthrie et al., 1998; Sheveland, 1994).

In its most extreme form, this approach is known as **whole language instruction**: teaching reading exclusively by using authentic reading materials (Goodman, 1989; Goodman & Goodman, 1979; C. Weaver, 1990). Basic knowledge and skills related to reading, such as letter-sound correspondences and word recognition, are taught solely within the context of real-world reading and writing tasks, and far less time is devoted to instruction of basic skills than is true in more traditional reading programs. Instead, students spend a great deal of time writing and talking with their classmates about what they have read.
Numerous research studies have been conducted comparing the effectiveness of whole-language and basic-skills approaches to reading instruction. Studies with kindergartners and first graders find that whole-language approaches are often more effective in promoting emergent literacy—familiarity with the nature of print, knowledge that books can be sources of entertainment and pleasure, and so on (Purcell-Gates, McIntyre, & Freppon, 1995; Sacks & Mergendoller, 1997; Stahl & Miller, 1989). When children must actually read text, however, basic-skills approaches—in particular, a focus on developing phonological awareness and knowledge of letter-sound relationships—seem to be superior, especially for children from low-socioeconomic backgrounds and for students who show early signs of a reading disability (Adams, 1990; Stahl & Miller, 1989; Stanovich, 2000). Considering such research, many theorists now urge that teachers strike a balance between whole-language activities and basic-skills instruction (Biemiller, 1994; Mayer, 1999; Pressley, 1995).

**Use motivating activities to teach basic reading skills.** Even when we do teach basic skills such as letter-sound correspondences, word decoding, and use of context clues, we do not necessarily need to teach them through dry, drill-and-practice workbooks. Such workbooks are often not terribly motivating for students, who may see assignments in such books primarily as exercises to complete as quickly as possible (E. H. Hiebert & Raphael, 1996). With a little thought, we can develop interesting activities to teach almost any basic skill. Here are three examples:

- Playing a game of “Twenty Questions” that begins with a hint such as, “I’m thinking of something in the classroom that begins with the letter B”
- Giving students a homework assignment to bring in three objects that begin with the letter T and three more that end with the letter T
- Using children’s poems that illustrate common letter patterns (e.g., Dr. Seuss’s *The Cat in the Hat* or *Green Eggs and Ham*)

We can also teach these and other basic skills, such as using context clues to identify unfamiliar words and making predictions about what will happen next, while students read interesting storybooks with simple language and colorful illustrations (Clay, 1985).

**Engage students in group discussions about the things they read.** Our students can often construct meaning more effectively from the things they read when they discuss their readings with their classmates. For instance, we can form “book clubs” in which students lead small groups of classmates in discussions about specific books (McMahon, 1992). We can hold “grand conversations” about a particular work of literature, asking students to share their responses to questions with no single right answers—perhaps questions related to interpretations or critiques of various aspects of a text (Eeds & Wells, 1989; E. H. Hiebert & Raphael, 1996; Keefer, Zeitz, & Resnick, 2000). And we can encourage students to think about a piece of literature from the author’s perspective, posing such questions as “What’s the author’s message here?” or “Why do you think the author wants us to know about this?” (Beck, McKeown, Worthy, Sandora, & Kucan, 1996). Group discussions may not only help students understand what they are reading but may also provide a means through which they can form friendships and in other ways address their social needs (Alvermann, Young, Green, & Wisenbaker, 1999).

Students develop additional insights about reading when they become authors themselves and share their writing with their classmates. We turn our attention now to the nature of writing and to strategies for helping students become proficient writers.

**Writing**

The second graders in our opening case study clearly have a long way to go in their writing development. This is hardly surprising, because writing is a very complex and multifaceted skill. In addition to mastering the vocabulary and syntax of the English language, students must also master
elements of written language—spelling, punctuation, capitalization, indentation, and so on—that aren’t directly evident in speech. Yet good writing goes far beyond knowing how to spell words, where to put periods and commas, and when to capitalize. More importantly, it involves putting words together in such a way that readers can construct a reasonable understanding of the author’s intended message. Let’s look more closely at the processes that skilled writing involves.

The Nature of Skilled Writing

As you might guess, students who are better readers also tend to be better writers; this correlation is undoubtedly due, at least in part, to the fact that general language ability—knowledge and effective use of grammar, vocabulary, and so on—provides a foundation for both reading and writing (Perfetti & McCutchen, 1987; Shanahan & Tierney, 1990). In addition to proficiency in English, the following processes are central to effective writing:

Planning  Setting one or more goals for a writing project
           Identifying relevant knowledge
           Organizing ideas

Drafting  Writing a first draft
           Addressing mechanical issues

Metacognition  Metacognitively regulating the writing process

Revision  Editing (i.e., identifying weaknesses)
           Rewriting

These processes are summarized in Table 8.1. Skilled writing typically involves moving back and forth among them throughout a writing project (Benton, 1997; Flower & Hayes, 1981; R. T. Kellogg, 1994).

Setting Goals

Certainly the first step in any writing project is to determine what one wants to accomplish by writing. For example, I had two primary goals as I wrote this supplementary reading: (1) to provide an accurate synthesis of what psychologists and educators have discovered about how students learn and develop in the content areas and (2) to help my readers learn this information meaningfully, so that they can easily transfer it to their future instructional practices. But writers may have other goals instead—perhaps to entertain, describe, report, or persuade. I suspect that many students have only one, not terribly beneficial goal when they complete written classroom assignments: to write something that will earn them a good grade.

Expert writers identify specific goals before they begin writing, but beginning writers rarely give much thought to their objectives (Scardamalia & Bereiter, 1986; Sitko, 1998). As teachers, we must help our students establish clear goals for themselves before they begin to write, and such goals should focus more on conveying intended meanings successfully than on addressing such writing mechanics as spelling and punctuation (Langer & Applebee, 1987). For instance, we might ask our students to address questions such as these before they put pen to paper: Why am I writing this? Who am I writing for? (Englert, Raphael, Anderson, Anthony, & Stevens, 1991). By encouraging students to clarify their writing goals, we will almost certainly help them write more effectively (Ferretti, MacArthur, & Dowdy, 2000; Page-Voth & Graham, 1999).
### Table 8.1. Components of Skilled Writing

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<th>Process(es)</th>
<th>Challenges for Students</th>
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<tr>
<td>Setting goals</td>
<td>Students must decide what they want to accomplish through their writing.</td>
<td>Ask students to answer questions such as “Why am I writing this?” and “Who am I writing for?” before they begin to write.</td>
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<tr>
<td>Identifying relevant knowledge</td>
<td>Students must identify what they already know about a topic. In some cases, they must also conduct research to obtain the information they need.</td>
<td>Have students brainstorm ideas before they begin writing. Teach essential research strategies (e.g., finding information in the library or on the Internet).</td>
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<tr>
<td>Organizing ideas</td>
<td>Students must create a logical sequence in which to present their ideas.</td>
<td>Have students develop an outline before they begin writing. Teach specific structures that students might follow as they write (e.g., a structure for a persuasive essay, the typical elements of a short story).</td>
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<tr>
<td>Writing a first draft</td>
<td>Students must get their ideas on paper in a reasonably logical and coherent fashion.</td>
<td>Remind students that they must communicate their ideas in a way that their readers can understand. Give students some strategies for communicating effectively (e.g., using examples, analogies, or rhetorical questions). Ask students not to worry too much about spelling, punctuation, and capitalization in the first draft. When students know how to spell few if any words (especially in the early elementary grades), let them dictate their stories.</td>
<td></td>
</tr>
<tr>
<td>Addressing mechanics</td>
<td>Students must use correct word spellings and apply rules and conventions for grammar, punctuation, and capitalization.</td>
<td>Provide some systematic instruction in spelling, grammar, punctuation, and capitalization. Allow students to use spell and grammar checkers on word processing programs.</td>
<td></td>
</tr>
<tr>
<td>Metacognition</td>
<td>Students must continually monitor their writing for clarity and logical sequencing, and they must continually keep both their goals and their audience in mind.</td>
<td>Give students a list of questions to consider as they write (e.g., “Am I achieving my goal?” “Am I following a logical train of thought?”). Ask students to write for a specific, concrete audience (e.g., for a younger child or for a member of Congress). Have students write in pairs as a way of encouraging them to verbalize issues related to writing effectively.</td>
<td></td>
</tr>
<tr>
<td>Editing</td>
<td>Students must find mechanical errors; they must also identify problems in organization, clarity, and style.</td>
<td>Provide frequent, concrete, and constructive feedback about both content and mechanics. Have students meet to edit one another’s work.</td>
<td></td>
</tr>
<tr>
<td>Rewriting</td>
<td>Students must address the errors and problems they’ve identified during editing and eventually produce a clear, cohesive, and error-free text.</td>
<td>Encourage students to use a word processing program so that they can make changes more easily. Have students collaborate with one another as they make revisions.</td>
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</table>
Identifying Relevant Knowledge

Whether they write fiction or nonfiction, writers can write about only the things they know or believe. Thus, they must identify what they have already learned about a topic—knowledge acquired, perhaps, through formal instruction, independent reading, or personal experience—and then, if necessary, supplement it with additional research. Effective writers typically have a solid understanding of the content about which they are writing: They have learned it in a meaningful, well-organized, and elaborated fashion (Benton, 1997; R. T. Kellogg, 1994).

In some situations, we will, of course, need to teach our students various strategies for locating needed information in newspapers, at the library, or on the Internet. In other situations, we may simply need to help them retrieve helpful information from their long-term memories. For instance, as a prewriting activity, we might conduct small-group or whole-class discussions on the topics that students will be writing about (Boiarsky, 1982).

Organizing

After identifying what they know or believe about a topic, good writers typically spend a fair amount of time organizing their ideas (Berninger, Fuller, & Whitaker, 1996; Scardamalia & Bereiter, 1987). For instance, students can organize their thoughts using such tried-and-true methods as making a list, forming clusters of related ideas, or developing an outline (R. T. Kellogg, 1994). Furthermore, we can scaffold their first attempts at particular forms of writing by providing a structure for them. For instance, when asking students to write a persuasive essay, we might suggest that they follow four steps:

1. Develop a topic sentence.
2. List several reasons that support the topic sentence.
3. Determine whether each reason is likely to be convincing to readers; if necessary, modify it so that it is more convincing.
4. Develop an appropriate ending or conclusion. (based on Graham & Harris, 1988)

When we have students write short stories, we can teach them to incorporate the features that most stories have: a setting, a main character with certain thoughts and feelings, a problem situation, an outcome, and so on (Gambrell & Chasen, 1991; Graham & Harris, 1992).

Writing a First Draft

Converting one’s ideas into written language—a process known as translating—is possibly the most challenging part of effective writing. A good writer uses a wide variety of words and sentence structures to convey ideas, takes into account the prior knowledge that readers are likely to have, and puts words together in such a way that readers can easily construct intended meanings (Burnett & Kastman, 1997; Byrnes, 1996; Spivey, 1997).

Many students at all grade levels think of writing as a process of putting ideas on paper, rather than as a process of presenting ideas in a way that enables their readers to understand those ideas. Furthermore, students rarely elaborate in writing on the ideas they present; for instance, they are reluctant to analyze, synthesize, and evaluate them. In general, students’ writing tends to be knowledge telling rather than knowledge transforming (Bereiter & Scardamalia, 1987; Cameron, Hunt, & Linton, 1996; Greene & Ackerman, 1995; McCutchen, 1996). As examples, consider the following two essays, each one written by a small group of fourth graders; both essays were supposedly written to help younger children learn about electric circuits:
Example of knowledge telling:

Electric circuits are wires that when it’s closed electricity flows through and it’s circular. A generator is a magnet that spins around in coils. It powers up a city or town. A conductor is what makes electricity. It powers up electrical things. (Chambliss, 1998, p. 8; reprinted by permission)

Example of knowledge transforming:

**Electric Circuits They’ll Shock You**

You have energy inside of you that allows you to walk, run, jump, etc. There’s also another source of energy, electrical energy. It lets you turn on your light, run your computer, listen to the radio, and many other things.

But before you experiment let us caution you that electricity can be very dangerous so don’t experiment without adult supervision. Here are some safety precautions for when you experiment: Never touch the copper part of a wire. Do NOT leave liquid substances near electrical equipment. Do not open a battery without protection (it contains acid).

Now that you know the rules let me tell you about electricity. When you turn on your light that means you have made a circuit flow, when you turn off the light that means you broke the circuit. How does a light bulb light you ask? Well you have to have a complete circuit. Let all the equipment touch each other. The wires must touch the battery. The battery must touch the light. The light must touch the battery.

If you don’t understand how the circuit breaks, here is an example. When you are using the refrigerator, you open it, and all the air comes out. When you are not using the refrigerator, you close it, and the air no longer comes out.

Now that you know about electricity it won’t shock you the way it works. (Chambliss, 1998, p. 8; reprinted by permission)

When students engage in knowledge telling, they are likely to write their thoughts in the order in which they retrieve them from long-term memory, with little regard for constructing a cohesive, logical, and complete piece of written work. In contrast, when students engage in knowledge transforming, they tailor their presentation to the things that their intended audience is likely to know and systematically lead their readers toward a better understanding of the topic in question.

Students may knowledge-tell, rather than knowledge-transform, partly because they must consider so many different things—the content, the audience, spelling, grammar, punctuation, handwriting, and so on—when they write that their working memories simply cannot handle the load (Benton, 1997; Flower & Hayes, 1981; McCutchen, 1996). It is usually beneficial, then, to have students address only one or two aspects of the writing process at a time; for instance, we might ask them to plan and organize their thoughts before they actually begin writing and to ignore the mechanics of writing until after they have written their first draft (K. R. Harris & Graham, 1992; Treiman, 1993). We may also want to brainstorm with students about strategies for communicating ideas effectively—for instance, using examples, analogies, graphics, and rhetorical questions—to a particular audience (Chambliss, 1998). And we can illustrate knowledge transforming by showing students actual examples of how expert writers communicate their ideas (Byrnes, 1996; Englert et al., 1991).

**Addressing Writing Mechanics**

Expert writers have typically learned the mechanical aspects of writing—spelling, punctuation, capitalization, and proper syntax (correct word order, subject-verb agreement, etc.)—to a level of automaticity. Given the limited capacity of working memory, such automaticity is probably
essential if we want students to communicate their thoughts in a logical, well-organized, knowledge-transforming manner. Yet it makes little sense to postpone writing tasks until students have completely mastered writing mechanics; if we did so, our students might never have a chance to write!

Too much emphasis on writing mechanics is likely to discourage our students from wanting to write very much in the future. When we put writing mechanics aside for awhile—for the first draft in the case of older students and perhaps altogether in the case of very young ones—we are likely to see our students write more frequently and create longer and more complex texts (Clarke, 1988; Leu & Kinzer, 1995; Treiman, 1993). For instance, kindergartners and first graders can write a great deal using “invented spellings” that often only vaguely resemble actual words. Consider this kindergartner’s creation entitled “My Garden” (note that “HWS” is *house*):

```
THIS IS A HWS
THE SUN
WL SHIN
ND MI
GRDN
WL GRO
```

(Hemphill & Snow, 1996, p. 192)

If time and resources allow, and especially if we are teaching in the early elementary grades, we might even have our students initially dictate stories and compositions for someone else to write down (Scardamalia, Bereiter, & Goelman, 1982).

Eventually, of course, we must teach our students the conventions of written language and stress the importance of using those conventions for effective communication (Treiman, 1993). For instance, we should teach general rules of punctuation and capitalization, stress the importance of subject-verb agreement, and introduce various kinds of simple and complex sentences. And we will undoubtedly want to provide some explicit instruction in spelling. Theorists and practitioners have offered several strategies for spelling instruction:

- Point out letter-sound correspondences in how words are spelled.
- Draw analogies among words that are spelled similarly.
- Have students write each word several times as they study it.
- Stress the importance of correct spelling for enhancing a writer’s credibility.


**Metacognition**

Throughout the writing process, expert writers are metacognitively active: They monitor their progress and the effectiveness of what they have written, addressing questions such as these:

- Am I achieving my goal(s) for writing this piece?
- Am I explaining myself clearly?
- Am I following a logical train of thought?
- Am I giving examples to illustrate my ideas?
- Am I supporting my opinions with valid arguments?

The answers to such questions influence their subsequent courses of action.
Furthermore, skillful writers continually keep their anticipated readers in mind (R. T. Kellogg, 1994; Paris & Cunningham, 1996). When we speak with other people, we get constant verbal and nonverbal feedback from them; for instance, they ask questions when they don’t understand and let us know when they disagree with us. But when we write, we do so in isolation from our audience. We must therefore make assumptions about our readers’ prior knowledge, vocabulary level, cognitive maturity, and motivation for reading what we have written.

All too often, elementary and secondary students don’t metacognitively “supervise” what they are doing as they write; for instance, they give little thought to who their audience might be, and they engage in knowledge telling rather consciously trying to communicate their thoughts in a way that someone else can easily understand (Graham, Harris, & Troia, 1998; Sitko, 1998). This state of affairs is probably not surprisingly given the fact that, in most cases, the only person who actually reads their work is a teacher who may already be familiar with the ideas they are trying to present.

One way to enhance students’ metacognitive awareness and regulation of what they do (mentally) as they write is to explicitly teach and model various writing strategies—identifying the goals to be accomplished in a writing project, organizing one’s thoughts before starting to write, asking oneself questions about what has already been written, and so on—and initially give students the scaffolding they need to use these strategies (Graham et al., 1998). A second approach is to meet with students one-on-one and ask them to reflect on the strategies they’ve used while writing (e.g., “How did you decide to start the piece in this way?”; Sitko, 1998, p. 107). Yet another technique is to ask students to write for a particular audience, as the fourth graders who wrote the “Electric Circuits They’ll Shock You” essay did (Burnett & Kastman, 1997; Cameron et al., 1996; Sperling, 1996). For example, we might ask students to write a letter to people their own age who live in environments very different from their own—perhaps in a large city or in farm country (Benton, 1997; Kroll, 1984). Or we might ask them to imagine themselves in particular roles—perhaps as reporters investigating a news story or as travelers hoping to spread peace throughout the world (J. J. Schneider, 1998). Students as young as 7 or 8 can adapt their writing to different audiences when they understand who those audiences are (J. J. Schneider, 1998).

Editing

Try your hand at editing in the following exercise.

**EXPERIENCING FIRSTHAND What’s Wrong?**

Here is how one eighth-grade girl responded to the question, *How did the United States become a country?* As you read it, mark places that need revision.

The first people here were what we called the Native Americans they crossed over to America on a land Bridge or as some people say.

In Europue people where thinking the world was flat and if you sailed on and on you would fall of the world but Christopher Columbus did not beleave that he believed it was round. So Christopher Columbus sailed to America. Soon after Pilgrims came to get away from the Catholic religion. More people came over and keep pushing the Indians off their land and taking what was not theirs the Indians where willing to share it but americans just took it. Then the people wanted
to break away from Brittany. Then Americans fought with each other over many things like slaver.

And North won.

(courtesy of Dinah Jackson)

Now count how many times you marked these kinds of errors:

<table>
<thead>
<tr>
<th>Error Type</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spelling errors</td>
<td></td>
</tr>
<tr>
<td>Indentation errors</td>
<td></td>
</tr>
<tr>
<td>Punctuation errors</td>
<td></td>
</tr>
<tr>
<td>Run-on sentences</td>
<td></td>
</tr>
<tr>
<td>Capitalization errors</td>
<td></td>
</tr>
<tr>
<td>Problems of style</td>
<td></td>
</tr>
</tbody>
</table>

What kinds of problems did you focus on when you edited the student’s composition?

How much did you focus on writing mechanics (spelling, capitalization, etc.) in your editing? Did you identify any problems other than mechanical errors? Did you find the two factual errors? The Pilgrims wanted to leave the Church of England, not the Catholic church, and they left Britain, not Brittany (a region in France). Did you note any instances of unclear writing? For instance, in the phrase “taking what was not theirs” in the second paragraph, the meanings of what and theirs are not clear. And what about the overall style of the piece? The phrase “or as some people say” serves no purpose, and the last sentence is short and choppy. In general, the student has engaged in knowledge telling rather than knowledge transforming: She has simply written down her thoughts, apparently in the order in which she retrieved them from long-term memory, and made no attempt to tie them together into a coherent whole.

Unfortunately, when teachers provide feedback about students’ writing, they tend to focus more on mechanical errors than on problems with style, clarity, or cohesiveness (Byrnes, 1996). So it is not surprising that when students edit their own work, they, too, focus on mechanics (Berninger et al., 1996; Kellch, 1999; McCutchen, Kerr, & Francis, 1994). Many students, especially those in the elementary grades, believe that they are expressing themselves more clearly than they actually are; they have difficulty reading their own writing as another person might read it (Bartlett, 1982; Beal, 1996).

Our students can edit their writing more successfully when we give them criteria that they can use to judge their work (McCormick, Busching, & Potter, 1992). It is essential, too, that we provide feedback that addresses style, clarity, and cohesiveness as well as mechanics (Benton, 1997; Covill, 1997). (We should be careful, of course, that we balance criticism with a healthy dose of feedback about what students are doing well, so that we don’t discourage them from writing altogether!) Furthermore, we can ask students to read and respond to one another’s work (Benton, 1997; Cameron et al., 1996; Sperling, 1996); in the process, they may become better able to examine their own writing from the perspective of potential readers.

**Rewriting**

Good writers almost invariably revise the things they write; in the process, they tend to focus on problems of clarity and organization while keeping in mind the overall goals of their writing (Fitzgerald, 1992; Scardamalia & Bereiter, 1986). In contrast, children and adolescents rarely revise unless a teacher or other adult specifically urges them to do so; when they do rewrite, they tend to make only small, superficial changes (Beal, 1996; Fitzgerald, 1987).
Sometimes, students fail to address problems in clarity and organization because they haven’t located these problems to begin with (Fitzgerald, 1987). But our students may also not know how to revise their work. Researchers have identified several strategies through which we can help our students as they revise the things they’ve written:

- Schedule in-class time for revising so that students can get assistance when they need it.
- Before students begin rewriting, ask them to list five things they can do to make their writing better.
- Provide questions that students should ask themselves as they rewrite (e.g., “Is this confusing?” “Do I need another example here?” “Who am I writing this for?”).
- Occasionally have students work in pairs or small groups to help one another revise.

(Benton, 1997; Bereiter & Scardamalia, 1987; Cameron et al., 1996; De La Paz, Swanson, & Graham, 1998; Graham, MacArthur, & Schwartz, 1995; Graves, 1983; Kish, Zimmer, & Henning, 1994; Sitko, 1998; Webb & Palincsar, 1996)

Writing as a Facilitator of Learning

As you must surely have noticed in the preceding discussion, writing involves several cognitive processes that promote learning. Writers must retrieve from long-term memory the things that they already know about a topic. They must clarify and organize their thoughts sufficiently to communicate them to their readers. And a knowledge-transforming approach to writing requires writers to elaborate on the things they know—for instance, to put ideas in language that the intended audience can understand, to think of good examples, and to anticipate readers’ questions. So it is not surprising that writing about a topic, phenomenon, or problem-solving strategy enhances students’ understanding (Benton, 1997; Greene & Ackerman, 1995; Johanning, D’Agostino, Steele, & Shumow, 1999; Klein, 1999, 2000). As teachers, then, we should ask students to write frequently for two reasons: to enhance their writing ability and to enhance their learning more generally.

Developmental Changes in Writing

The nature and quality of students’ writing change in many ways throughout the elementary and secondary school years. In the early elementary years, writing projects typically involve narratives: Students write about their own personal experiences and create short, fictional stories (Hemphill & Snow, 1996). They have a hard time writing for an imagined audience and, as a result, engage in knowledge telling (rather than knowledge transforming) almost exclusively (Knudson, 1992; Perfetti & McCutchen, 1987). And of course, as was evident in the second graders’ compositions in the opening case study, students in the lower elementary grades are still working on the “basics” of spelling, grammar, punctuation, and capitalization.

In the later elementary grades, writing mechanics (e.g., many word spellings) are beginning to become automatic, enabling students to use more complex sentence structures and devote more effort to communicating their thoughts effectively on paper (R. E. Owens, 1996). Furthermore, they begin to think about how their readers might respond to what if they have written and so are more likely to proofread and revise their work (R. E. Owens, 1996). At this point, however, they do very little planning before they begin to write, and their writing continues to involve knowledge telling rather than knowledge transforming (Berninger et al., 1996).

We see several changes as students move through the secondary grades. First, students are more capable of analyzing and synthesizing their thoughts when they write, and so they are better able to write research papers and argumentative essays (Knudson, 1992; McCann, 1989; Spivey, 1997).
They are more likely to consider specific goals when they write and therefore to include only content directly relevant to those goals (Scardamalia & Bereiter, 1987). When asked to write about a particular topic, they retrieve and generate many more ideas than students in the elementary grades do (Scardamalia & Bereiter, 1986). Their sentences are more likely to vary in structure and frequently contain one or more dependent clauses (Byrnes, 1996). And in general, they compose more cohesive, integrated texts (Berninger et al., 1996; Byrnes, 1996; R. E. Owens, 1996; Spivey, 1997). At this point, too, although many students continue to engage in knowledge telling, we start seeing regular signs of knowledge transforming as well (Spivey, 1997). As an example, consider how this eighth grader answered the question, How did the United States become a country?

We became a country by way of common sense. The inhabitants on American soil thought it rather silly and ridiculous to be loyal to, follow rules and pay taxes to a ruler who has never seen where they live. King George III had never set foot (as far as I know) on American soil, but he got taxes and other things from those who lived here. When America decided to unite and dishonor past laws and rules, England got angry. There was a war. When we won, drew up rules, and accepted states America was born.

In a more poetic sense, we became a country because of who lived here and what they did. They actions of heros, heroines, leaders, followers, and everyday people made America famous, an ideal place to live. The different cultures and lifestyles made America unique and unlike any other place in the world. If you think about it, it’s like visiting the worlds at Epcot in Florida. You can go from country to country without leaving home. (courtesy of Dinah Jackson)

The student’s analogy between the United States and Disney World’s Epcot Center is knowledge transforming at its finest.

**General Strategies for Teaching Writing**

We’ve already identified numerous strategies for helping students develop specific aspects of the writing process. Here are several additional strategies to promote writing development more generally:

- **Assign authentic writing tasks.** Although we would like students to be able to write for a variety of audiences, in reality most of them write primarily for one person: their teacher (Applebee, 1984; Benton, 1997). By giving our students authentic, real-world writing tasks—having them write short stories for their classmates, letters to businesses and lawmakers, editorials for the local newspaper, e-mail messages to people in distant locations, and so on—we can encourage them to consider the language abilities and prior knowledge of their readers (e.g., Englert et al., 1991; Sugar & Bonk, 1998). Such tasks can also prompt students to set specific goals for writing and to acquire the writing skills they need to achieve those goals.

- **Offer students some choices about writing topics.** Students write more frequently, and in a more organized and logical fashion, when they are interested in what they are writing about (Benton, 1997; Garner, 1998). For instance, one high school English teacher, who noticed that several very capable students were failing his class because they weren’t completing assigned writing tasks, began having his students write about their own personal experiences and share them on the Internet with students in other classrooms; the teacher monitored their compositions for vulgar language but imposed no other restrictions. The students suddenly began writing regularly, presumably because they could write for a real audience and could now choose their own topics (Garner, 1998). As Chapter 12 of the textbook points out, choices enhance students’ sense of self-determination, which in turn enhances their intrinsic motivation to complete assigned tasks and, hence, to develop their academic skills.
INTO THE CLASSROOM: Promoting Reading and Writing Skills

• Help young children develop phonological awareness.
  A kindergarten teacher suggests to his class, “Let’s see how many words we can think of that rhyme with the word gate. I’ll write the words on the chalkboard. Let’s see if we can think of at least eight words that rhyme with gate.”

• Help students develop automaticity in word recognition and spelling, but do so within the context of authentic reading and writing activities as much as possible.
  A second-grade teacher has her students read Dr. Seuss’s The Cat in the Hat, a book that repeats many of the same words (e.g., cat, hat, thing) over and over again.

• Have students discuss with peers the things they are reading and writing.
  A middle school teacher has his students meet in small groups to read their short stories to one another. As each student reads his or her story, other group members ask questions for clarification and make suggestions about how to make the story better. Later, students consider their classmates’ comments as they revise their stories.

• Scaffold students’ efforts as they work on increasingly more challenging reading and writing tasks.
  A high school English teacher gives students a format to follow when writing a research paper: an introductory paragraph that describes the topic of the paper, at least three different sections within the paper that address different aspects of the topic (each one beginning with a new heading), and a “Conclusion” section that summarizes and integrates the main ideas of the paper.

• Address reading and writing skills in all areas of the curriculum.
  An eighth-grade social studies teacher gives her students an article to read from Newsweek magazine. Knowing that the reading level of the article may be challenging for many of her students, she gives them specific questions to answer as they read the article.

• Use peer groups to promote effective writing skills. Earlier we noted the value of using peer groups to help students edit and revise their writing. In fact, we may want to have our students actually write together as well. Several studies have shown that when students collaborate on writing projects, they produce longer and more complex texts, revise more, and enhance one another’s writing skills (Daiute, 1986, 1989; Daiute & Dalton, 1993).

• Encourage students to use word processing programs. Word processing programs encourage students to revise; after all, it is much easier to change words and move sentences when one is working on a computer rather than on paper (Cochran-Smith, 1991; R. T. Kellogg, 1994). Furthermore, by taking over some of the mechanical aspects of writing, word processing can lessen the load on working memory, enabling students to devote more working memory capacity to the overall quality of writing (Jones & Pellegrini, 1996). As an illustration, consider what the same first grader wrote by hand and by computer (Jones & Pellegrini, 1996):

  By hand:
  Some busy wut to play boll But thay cnat play Boll Be cus the Big Busys and the grul wit to tale on them (p. 711)

  By computer:
  The man cooks some soup and he cooks carrots in the soup and the king gives the man a big hat, and the man goes to the house and the man shows the hat cap to the children. (p. 711)

A big difference, wouldn’t you say?
Include writing assignments in all areas of the curriculum. Writing shouldn’t be a skill that only elementary teachers and secondary English teachers teach. In fact, writing takes different forms in different disciplines; for instance, writing fiction is very different from writing a science laboratory report, which in turn is very different from writing an analysis of historical documents. Ideally, all teachers should teach writing to some degree, and, especially at the secondary level, they should teach the writing skills specific to particular academic disciplines (Burnett & Kastman, 1997; Sperling, 1996).

Not only is writing often very different in different subject areas, but the very nature of thinking and learning can be quite different as well. You will see what I mean as we explore mathematics, science, and social studies.

Mathematics

Mathematics probably causes more confusion and frustration, for more students, than any other subject in the school curriculum. The hierarchical nature of the discipline may be partly to blame: To the extent that students don’t completely master mathematical concepts and procedures at one grade level, they lack necessary prerequisites for learning math successfully in later grades. As increasingly more complex and abstract concepts and procedures are introduced over the years, students must resort more and more frequently to rote, meaningless learning.

Mathematics is actually a cluster of domains—arithmetic, algebra, geometry, statistics and probability, and so on—that comprise different methods of representing situations and strategies for solving problems (De Corte, Greer, & Verschaffel, 1996). Nevertheless, we can identify several key components that underlie effective mathematical reasoning across the board. As we do so, we will also identify many strategies that can help our students become successful mathematical thinkers.

The Nature of Mathematical Reasoning

Mathematical thinking and problem solving typically require the following:

- Understanding numbers and counting
- Understanding central mathematics concepts and principles
- Encoding problem situations appropriately
- Mastering a variety of problem-solving procedures
- Relating problem-solving procedures to mathematical concepts and principles
- Relating mathematical principles to everyday situations
- Developing effective metacognitive processes and beliefs

Understanding Numbers and Counting

Many children begin counting before their third birthday, and most 3- and 4-year-olds can count to ten correctly (Geary, 1994). Five-year-olds can often count far beyond ten (perhaps to 50), but they may get confused about the order of such numbers as 70, 80, and 90 (Fuson & Hall, 1983). Furthermore, most 5-year-olds have mastered several basic principles of counting, including these:

- One-one principle. Each object in the group being counted must be assigned one and only one number word; in other words, you say “one” while pointing to one object, “two” while pointing to another, and so on until every object has been counted once.
• **Cardinal principle.** The last number word counted indicates the number of objects in the group; in other words, if you count up to five when counting objects, then there are five objects in the group.

• **Order-irrelevance principle.** A group of objects has the same number regardless of the order in which they are counted. (Gallistel & Gelman, 1992; Gelman & Gallistel, 1978)

Many 5-year-olds have also developed simple procedures for adding and subtracting, procedures that they have, in most cases, developed on their own (Bermejo, 1996; Correa, Nunes, & Bryant, 1998; Geary, 1994). If they want to add a group of five objects and a group of three objects, they won’t necessarily begin counting with *one*; instead, they may begin with *five* and then count the smaller group: “Five, six, seven, eight.” They might do something similar for subtracting, starting with the original number of objects and then counting down the number of objects removed: “Eight, seven, six, five.” Eventually, children no longer need to have the objects in front of them when they add and subtract; instead, they use their fingers to represent the objects (Bermejo, 1996).

Certainly not all young children acquire the basic understanding of counting, numbers, addition, and subtraction just described. Yet such understanding forms the basic foundation for the arithmetic that we teach in the early elementary years. Especially if we are teaching kindergartners or first graders, we must determine what our students do and do not know about numbers and remediate any weaknesses in their understanding. Numerous activities and games involving counting, comparing quantities, adding, and subtracting—always using concrete objects—are likely to be beneficial. We may also want to use a number line to help young children develop an understanding of how numbers relate to one another (Greeno, Collins, & Resnick, 1996; Griffin, Case, & Capodilupo, 1995; Griffin, Case, & Siegler, 1994).

**Understanding Central Concepts and Principles**

In addition to a basic understanding of numbers, mathematical reasoning requires an understanding of many concepts and principles. For instance, students must eventually master such concepts as *negative number*, *right angle*, and *variable* and such principles as these:

• Multiplying a positive number by a negative number always yields a negative number.

• The three angles of a triangle always have a total of 180°.

• When an equation of the form $ax + by + c = 0$ is plotted on a graph, all possible solutions for $x$ and $y$ form a straight line.

Growing children are unlikely to develop such concepts and principles on their own; instead, some degree of formal instruction seems to be necessary (De Corte et al., 1996; Geary, 1994; Ginsburg, Posner, & Russell, 1981).

The more abstract mathematical concepts and principles are, the more difficulty our students are likely to have understanding them (Byrnes, 1996). With a little creativity, we can translate many abstract mathematical ideas into concrete form; Figure 8.1 provides examples.

**Encoding Problems Appropriately**

As noted in Chapter 8 of the textbook, an essential step in solving a problem is to encode it—that is, to think of it as being a certain *kind* of problem. For instance, you would immediately categorize the following problem:
Figure 8.1  Illustrating abstract mathematical concepts and principles in concrete ways
Mary has five marbles. John gave her seven more. How many does she have altogether?

as an addition problem. And you should recognize this problem:

I have a carpet that is 45 square feet in area. It is 4 feet longer than it is wide. What are the dimensions of my carpet?

as an area-of-a-rectangle problem. You might also identify it as an algebra problem, because the two numbers you need to calculate the area (the width and length) are unknowns.

At the high school level, encoding algebra problems poses a challenge for many students (Clement, 1982; Geary, 1994). Furthermore, students of all ages tend to have difficulty encoding relational problems—problems in which only comparative numbers are given—and hence are often unable to solve problems such as this one:

Laura is 3 times as old as Maria was when Laura was as old as Maria is now. In 2 years Laura will be twice as old as Maria was 2 years ago. Find their present ages. (Mayer, 1982, p. 202)

Even college students have trouble encoding and solving this problem (Mayer, 1982). (Laura is 18 and Maria is 12.)

Chapter 8 in the textbook offers several suggestions for helping students encode problems more effectively: We can give them real objects or pictures that can help them think about a problem in concrete terms, encourage them to draw their own pictures or diagrams, and point out features of a problem that should remind them of similar problems. Several additional strategies are useful as well (Mayer, 1999). We can give students a large number of problems and ask them only to categorize the problems, not to solve them. We can give them problems with irrelevant as well as relevant information (e.g., in the “carpet” problem presented earlier, we might include information about how old the carpet is or how much it costs per square yard). And we should definitely mix different kinds of problems together (e.g., problems requiring addition, subtraction, multiplication, and division) so that students get in the habit of encoding different problems differently.

Mastering Problem-Solving Procedures

Many mathematical problem-solving procedures involve specific algorithms that, when correctly applied, always yield a correct answer. For instance, students learn algorithmic procedures for doing long division, multiplying and dividing fractions, and solving for $x$ in algebraic equations. Problem-solving heuristics sometimes come into play as well. For instance, there aren’t always specific algorithms that students can use in geometric proofs. As an illustration, let’s use the following problem from Chapter 8 in the textbook:
There is no single “right” way to prove this point. Instead, we might experiment with the situation, perhaps extending some of the lines and considering other angles, like this:

![Diagram of intersecting lines](image)

By using principles related to the angles of triangles and intersecting lines, we can eventually prove that, yes, lines PQ and RS must be parallel.

As teachers, we can do several things to help students master mathematical procedures. In some cases—for instance, in basic addition, subtraction, multiplication, and division—we may want to replace algorithms with quickly retrievable facts; after all, retrieving $5 + 3 = 8$ uses less working memory capacity than an algorithm such as counting “five . . . and six, seven, eight.” We should also encourage students to use external forms of “storage” to reduce the working memory load, perhaps by using their fingers or pencil and paper to keep track of numbers or other elements of a problem. We can use concrete manipulatives to illustrate what might otherwise be fairly abstract procedures (Fuson & Briars, 1990). For example, we might demonstrate the rationale behind “borrowing” in subtraction by using toothpicks, some of which have been bundled into groups of ten or one hundred (see Figure 8.2). We can provide worked-out examples to illustrate such complex procedures as solving quadratic equations (Mayer & Wittrock, 1996; Mwangi & Sweller, 1998; Zhu & Simon, 1987). Ultimately, however, we must help our students understand why the mathematical procedures they use are appropriate. This particular point is so important that I address it separately in the following discussion.

**Relating Procedures to Concepts and Principles**

**EXPERIENCING FIRSTHAND  Quarters and Dimes**

See whether you can solve this problem before you read further.

The number of quarters a man has is seven times the number of dimes he has. The value of the dimes exceeds the value of the quarters by two dollars and fifty cents. How many has he of each coin? (Paige & Simon, 1966, p. 79)

If you found an answer to the problem—any answer at all—then you overlooked an important point: Quarters are worth more than dimes. If there are more quarters than dimes, the value of the dimes cannot possibly be greater than the value of the quarters. The problem makes no sense, and so it cannot be solved.

Unfortunately, when our schools teach mathematical problem solving, they often focus on teaching procedures for solving problems while omitting explanations of why the procedures work; in other words, they don’t relate the procedures to basic concepts and principles of mathematics (Cooney,
1991; J. Hiebert & Lefevre, 1986; Perkins & Salomon, 1989). For example, perhaps you can recall learning how to solve a long division problem, but you probably don't recall learning why you multiply the divisor by each digit in your answer and then write the product in a particular location below the dividend. Or perhaps you were taught that the words all together in a word problem indicate that addition is called for and that the word left means you should subtract.

When students learn mathematical procedures at a rote level, without understanding the concepts, principles, and general logic behind them, they may often apply them “unthinkingly” and inappropriately (Carr & Biddlecomb, 1998; Perkins & Simmons, 1988; Resnick, 1989; Silver, Shapiro, & Deutsch, 1993). As a result, they may obtain illogical or physically impossible results. Consider the following instances of meaningless mathematical problem solving as examples:

Figure 8.2 Illustrating a problem-solving algorithm with concrete manipulatives
• A student is asked to figure out how many chickens and how many pigs a farmer has if the farmer has 21 animals with 60 legs in all. The student adds 21 and 60, reasoning that, because the problem says “how many in all,” addition is the logical operation (Lester, 1985).

• A student uses subtraction whenever a word problem contains the word left—even when a problem actually requiring addition includes the phrase “John left the room to get more apples” (Schoenfeld, 1982).

• A student learns the process of regrouping (“borrowing”) in subtraction. In subtracting a number from 803, the student may “borrow” from the hundreds column, but only add 10 to the ones column (Resnick, 1989). Here is an example:

\[
\begin{array}{c}
  \text{71} \\
  \text{803} \\
- \text{507} \\
  \hline
  \text{296}
\end{array}
\]

(The correct answer, of course, is 296.)

Rather than simply teach mathematical procedures at a rote level, we should help students understand why they do the things they do to solve problems (Greeno, 1991; Griffin & Case, 1996; Perry, 1991; Rittle-Johnson, Siegler, & Alibali, 2001). For instance, we can relate regrouping procedures (“carrying” and “borrowing”) in addition and subtraction to the concept of place value—the idea that a number in the second column from the right indicates the number of tens, the number in the third column indicates the number of hundreds, and so on (Byrnes, 1996). By showing our students the logic behind problem-solving procedures, we increase the likelihood that they will apply those procedures at appropriate times and obtain plausible results.

**Relating Mathematics to Everyday Situations**

Ultimately, learning mathematics is of little use unless students can apply it to real-world situations. Word problems are often used to help students make the connection between formal mathematics and everyday life. Yet traditional word problems alone are probably insufficient to enable most students to bridge the gap between classroom math and everyday situations (De Corte et al., 1996). First, word problems are typically well-defined: They provide all the information students need to know and pose a specific question that students must answer. In contrast, the real world rarely presents such problems: Some necessary numbers or measures may be missing, irrelevant information may be present, and perhaps the exact question to be answered is not clearly specified. (See Chapter 8 in the textbook for a discussion of well-defined versus ill-defined problems.)

In the following exercise, we discover a second difficulty with word problems.

**EXPERIENCING FIRSTHAND  Busing the Band**

Take a minute to solve the following problem. Feel free to use a calculator if you have one handy.

The Riverdale High School marching band is traveling to Hillside High School to perform in the half-time show at Saturday’s football game. The school buses owned by the Riverdale School District can transport 32 passengers each. There are 104 students in the Riverdale band. How many buses will the band director need to request to transport the band to Hillside on Saturday?
Did you get the answer 3.25? If so, think about it for a moment. How is it possible to have 3.25 buses? What in the world is .25 of a bus? In actuality, the band director must request four buses for Saturday’s game. If you fell into my trap, you’re not alone. Many students develop the habit of solving word problems based on numerical information alone and overlook the realities of the situation with which they are dealing (De Corte et al., 1996).

In addition to using word problems, then, many theorists suggest that we engage students in tasks that require them to identify, on their own, the specific mathematical problems they need to solve in order to complete the tasks successfully (De Corte et al., 1996; J. Hiebert et al., 1996; Lester et al., 1997). For example, we might have our students work collaboratively to collect and then analyze large sets of data while studying their local ecology (Roth, 1996). We might take them grocery shopping, asking them to consider not only the “best buys” for various products but also how much cupboard space they have for storage (Lave, 1988). And we can ask them to bring to class some of the mathematical problems they encounter at home (Resnick, Bill, Lesgold, & Leer, 1991).

**Developing Metacognitive Processes and Beliefs**

Like virtually any other complex cognitive task, mathematical problem solving involves metacognition: The successful student must choose one or more appropriate problem-solving strategies, monitor progress toward the problem goal, and recognize when a solution has been reached (Carr & Biddlecomb, 1998; Schoenfeld, 1992). Rather than assume that our students will acquire these metacognitive processes on their own, we should probably teach such processes explicitly (Cardelle-Elawar, 1992). For instance, we can give students practice in identifying situations in which they don’t have all the information they need to answer a question. We can also give them problems requiring two or more separate procedures, ask them to list the specific steps necessary to solve the problems, and suggest that they cross off each step as they accomplish it.

An additional aspect of metacognition is being aware of the processes one is using, yet many elementary and secondary school students do not actively reflect on what they are doing as they solve mathematical problems (Carr & Biddlecomb, 1998). We can encourage such reflection by engaging students in group discussions about how best to approach particular problems (more about such discussions shortly) and by asking them to explain in writing why they solved a problem as they did (Carr & Biddlecomb, 1998; Johanning et al., 1999).

We must make sure, too, that our students’ beliefs about mathematics are conducive to effective learning and problem solving in math. Unfortunately, many students, even at the high school level, have several counterproductive beliefs:

- Mathematics is a collection of meaningless procedures that must simply be memorized.
- Mathematical problems always have one and only one right answer.
- One will either solve a problem within a few minutes or else not solve it at all.
- There’s only one right way to solve any particular math problem. (Schoenfeld, 1988, 1992)

When we teach mathematics, we must certainly be aware of students’ beliefs about math and take steps to correct any erroneous ones. For instance, as mentioned before, we can make mathematical procedures meaningful by relating them to concepts and principles students have already learned, and we can engage students in discussions about the variety of approaches possible for any particular problem. In addition, we can present problems that have multiple answers or require considerable time and persistence to solve.
Developmental Changes in Mathematical Understanding

As noted earlier, many (but not all) students first enter school having some proficiency in counting and some understanding of numbers. In the early elementary grades, we need to solidify these capabilities and expand them to include an understanding of addition and subtraction; later, we must expand them to include multiplication and division as well. But rather than ignore any strategies that students may have developed on their own—for instance, using their fingers to keep track of numbers or to add and subtract—we should probably encourage them to use existing strategies that seem to work effectively for them. They will eventually discard their early strategies as they acquire more efficient ones (Geary, 1994; Siegler, 1989).

The mathematics curriculum at the upper elementary grades typically includes an introduction to such proportions as fractions and decimals. Even first graders can understand simple fractions (e.g., 1/2, 2/3) if they can relate such fractions to their own, concrete reality (Empson, 1999). Yet the ability to reason more generally and effectively about proportions typically does not appear until students are, on average, about 11 or 12 years old (see Chapter 2 in the textbook). If school district objectives give us little choice about teaching proportions or other concepts that, from a developmental perspective, are going to be especially challenging for students, then we must present as many concrete and real-world examples of these concepts as possible.

In the middle school, junior high, and high school grades, mathematics instruction focuses increasingly on abstract ideas such as irrational numbers, \( \pi \), infinity, and variable. Over time, mathematical concepts and principles gradually become more and more removed from the concrete realities with which students are familiar. Perhaps it is no surprise, then, that students’ anxiety about mathematics peaks during the high school years (Geary, 1994). Two general strategies can help us keep math anxiety within reasonable limits. First, we must continue to use concrete examples and experiences to illustrate mathematical ideas even in high school. And second, we must make sure that our students truly master the concepts and procedures they will need when they proceed to more difficult topics.

General Strategies for Teaching Mathematics

Throughout this section we have identified specific strategies for helping students learn and use mathematics effectively. Following are three more general strategies:

• **Have students tutor one another in mathematics.** When students tutor one another in math, both the tutor and the student being tutored seem to learn from the interaction. Peer tutoring can occur within a single classroom, with students pairing off differently on different occasions, depending on which students have and have not mastered a particular idea (Fuchs, Fuchs, & Karns, 1995; Fuchs et al., 1996). But it can also happen in a cross-age fashion, with older students tutoring younger ones. In one situation, for instance, fourth graders who were doing relatively poorly in math served as arithmetic tutors for first and second graders; the tutors themselves showed a substantial improvement in arithmetic problem-solving skills (Inglis & Biemiller, 1997).

Why does peer tutoring help the tutors as well as the students being tutored? Theorists believe that by explaining something to someone else, the tutors must first clarify it in their own minds. Furthermore, tutors may have to provide several examples to help their partners understand a concept or procedure; developing such examples requires the tutors to elaborate on what they know—always a good strategy from a cognitive processing perspective.

• **Hold small-group or whole-class discussions about mathematical problems.** A growing body of research supports the effectiveness of group discussions for enhancing students’ mathematical understanding (Carr & Biddlecomb, 1998; Cobb et al., 1991; J. Hiebert & Wearne, 1992; Lampert,
One common strategy is to ask students to identify (perhaps invent) and defend various ways of solving a particular problem (Brenner et al., 1997; Ginsburg-Block & Fantuzzo, 1998; Kline & Flowers, 1998; Lampert, 1990). For example, at the second grade level, students might develop their own strategies for adding two- and three-digit numbers (J. Hiebert & Wearne, 1996). At the high school level, they might derive their own set of geometric theorems (Healy, 1993).

Many theorists believe—and some research supports their belief—that when we encourage students to invent and justify mathematical procedures and principles within a group context, we also encourage them to construct a more meaningful understanding of mathematics (Cobb, 1994; J. Hiebert et al., 1997; Lampert, Rittenhouse, & Crumbaugh, 1996). Furthermore, if particular students have misconceptions that lead them to develop inappropriate procedures or principles, then their classmates may quickly object to their ideas. But to create a climate in which students feel free to argue with one another about mathematics, we must communicate two messages very clearly—that as a group, we “agree to disagree” and that, as lifelong learners, we are all apt to be wrong some of the time (J. Hiebert et al., 1997; Lampert et al., 1996).

- Have students use calculators and computers frequently. On some occasions, we will probably want students to do calculations by hand; for instance, this will often be the case when students are first mastering such operations as addition, subtraction, multiplication, and division. But eventually, especially as students begin dealing with complex mathematical situations and problems, we may want to help them ease the load on working memory by encouraging them to use calculators or computers to do simple calculations. Calculators and computers also enable students to experiment with mathematics—for example, to graph an equation and then see how the graph changes when the equation is modified in particular ways (De Corte et al., 1996; Pressley, 1995).

Chapter 4 in the textbook introduces the notion of distributed intelligence—the idea that people can perform more complex tasks, and therefore can behave in a more “intelligent” fashion, when they have the support of their social and physical environments. Peer groups and technology are two examples of such environmental support. There is no reason why we or our students should think of mathematics as something that must be done in isolation from other people and without the use of modern technology. The same is true for science as well, and we turn to this subject area now.

Science

Historically, science as a discipline has had two major goals: to describe and to explain what people observe in nature (Mayer, 1999). Some of the things you studied in science were primarily descriptive in content. For instance, you probably studied characteristics of the planets in our solar system, discovered that water expands when it freezes, and examined the ways in which vertebrates and invertebrates are different. But you probably also studied possible explanations—theories—about natural phenomena. For instance, you may have considered theories about how the universe began, why water expands when it freezes, or how various animal species evolved.

Actually, you began learning science long before you entered school as a kindergartner or first grader. In your early explorations of the world, you learned that objects usually fall toward the earth when you let go of them, that water freezes when it gets cold, and that dogs and cats have four legs whereas birds have two legs and fish have none. Children rarely come to school as “blank slates” when it comes to science.

Not only have young learners already made numerous observations about the world, but they have also constructed their own explanations—their personal theories—for those observations. In some cases, these theories are reasonably accurate. For example, by the time children are 6 years old, most
of them have an intuitive understanding of differences between living things and inanimate objects: Both plants and animals grow and reproduce, and animals can typically move themselves around, whereas inanimate objects can neither grow nor go of their own accord (Hatano & Inagaki, 1996; Massey & Gelman, 1988). Yet children also acquire many misconceptions about the world. For example, most of them initially believe that the earth is flat and motionless and that the sun and stars revolve around it (Vosniadou, 1991).

Most contemporary theorists suggest that learning science is very much a constructive process: As learners gather more and more information about the world around them, they construct increasingly complex and integrated theories (diSessa, 1996; Driver, 1995; Wellman & Gelman, 1992; Wittrock, 1994). Children’s early observations of the world provide a foundation upon which formal science instruction in school can more effectively build. At the same time, the misconceptions that emerge in the early years often hinder children’s ability to develop more scientifically acceptable understandings of natural phenomena.

**The Nature of Scientific Reasoning**

Ideally, a school science curriculum must help students begin to think about the phenomena they observe in the same ways that adult scientists do. Here are some abilities that such reasoning includes:

- Investigating scientific phenomena objectively and systematically
- Constructing theories and models
- Revising theories and models in light of new evidence or better explanations
- Applying scientific principles to real-world problems
- Metacognitively supervising the reasoning process

**Investigating Scientific Phenomena**

At this point, I hope that you have already conducted experiments with a pendulum, either by completing the “Pendulum Problem” exercise presented in Chapter 2 of the textbook or by doing “The Pendulum Experiment” on the *Simulations in Educational Psychology and Research* CD at the back of the text. (If you have not done one of these, now would be a good time.) If you experimented as a true scientist would, then you engaged in two processes essential to scientific reasoning: formulation and testing of hypotheses and separation and control of variables. In particular, you identified several possible causes of a pendulum’s oscillation rate (your hypotheses), perhaps including the weight of the hanging object, the length of the string, the force with which the pendulum is pushed, and the height from which the object is dropped. You then tested your hypotheses by changing one variable at a time and keeping the other three constant. For instance, you might have varied the weight at the bottom of the pendulum while always keeping the length of string, force of push, and height of drop the same. If the oscillation rate changed each time you changed the weight, you would know that weight has an effect; if it didn’t change, then you would know that weight is irrelevant. You might have experimented with length, force, and height in a similar manner (always keeping the other three variables constant) and once again looked for resulting differences in oscillation rate.

To study a phenomenon objectively, scientists follow a systematic sequence of steps, or scientific method, that commonly includes formulating and testing hypotheses as well as separating and controlling variables. Furthermore, scientists must make observations that specifically relate to their hypotheses. This task is not necessarily as easy as it might seem, as the following exercise demonstrates.
Each of the cards above has a letter on one side and a number on the other side. Consider the following rule, which may or may not be true about the cards:

*If a card has a vowel on one side, then it has an even number on the other side.*

Which one or more cards must you turn over to determine whether the rule is true for this set of cards? Don’t turn over any more cards than you have to. Make your selection(s) before you continue reading. (modeled after Wason, 1968)

Many students, especially those in the elementary grades, fail to separate and control variables when they test their hypotheses (e.g., they might change weight and length simultaneously when experimenting with a pendulum), making their observations essentially uninterpretable (Pulos & Linn, 1981; Schauble, 1990, 1996). Furthermore, students of all ages (even college students) have a tendency to look for evidence that confirms their hypotheses but to ignore evidence that runs counter to their hypotheses—a phenomenon known as confirmation bias (Kuhn, Amsel, & O’Loughlin, 1988; Minstrell & Stimpson, 1996; Schauble, 1990). For example, when students in a high school science lab observe results that contradict what they expected to happen, they might complain that “Our equipment isn’t working right” or “I can never do science anyway” (Minstrell & Stimpson, 1996).

In our science lessons and courses, we want our students to be able to separate and control variables so that they can test various hypotheses in a systematic fashion. We also want them to be able to determine whether the information they obtain confirms or disconfirms their existing hypotheses and beliefs. One obvious way to accomplish both objectives, of course, is to engage them regularly in experimentation. Such experiments can occur in both traditional school laboratories and outside (field) settings. A growing body of research tells us, however, that students often need considerable scaffolding to conduct meaningful experiments and to interpret the results appropriately. Following are several ways to provide such scaffolding:

- Present situations in which only two or three variables need to be controlled, especially when working with elementary students.
- Use situations with which students are familiar and so have relevance to students’ lives (e.g., see the fishing situation depicted in Figure 2.4 in the textbook).
• Ask students to identify several possible hypotheses about cause-effect relationships before beginning to experiment.

• Provide regular guidance, hints, and feedback regarding the need to control variables and evaluate observations objectively.

• Ask questions that encourage students to make predictions and reflect appropriately on their observations (e.g., “What do you think will happen?” “What is your evidence?” “Do you see things that are inconsistent with what you predicted?”).

• Point out occasions when students obtain information that contradicts the hypotheses they are testing.

• Ask students to summarize their findings. (Byrnes, 1996; Carey, Evans, Honda, Jay, & Unger, 1989; Howe, Tolmie, Greer, & Mackenzie, 1995; Kuhn et al., 1988; Metz, 1995; Minstrell & Stimpson, 1996; Ruffman, Perner, Olson, & Doherty, 1993; White & Frederiksen, 1998)

Constructing Theories and Models

An essential part of learning science is acquiring increasingly complex and integrated understandings of various natural phenomena. Scientific understanding sometimes takes the form of a theory—an organized body of concepts and principles that have been developed to explain certain scientific phenomena. For example, when you studied biology, you probably studied the theory of evolution, a theory that encompasses interrelationships among such concepts as mutation, adaptation, and natural selection. Scientific understanding may also take the form of a model—knowledge of the components of a particular scientific entity and the interrelationships among those components. For instance, you probably have a mental model of our solar system that includes the sun and nine planets revolving around it at varying distances. If you look at Figures 3.1, 4.3, and 6.3 in the textbook, you’ll see physical representations of the models that some educational psychologists have developed for self-concept, intelligence, and human memory, respectively.

To some extent, students may acquire their knowledge of science through their own experimentation. But they should also study the concepts, principles, theories, and models that professional scientists currently use to make sense of the physical world (Driver, 1995; Hatano & Inagaki, 1996; Linn, Songer, & Eylon, 1996). The trick is for students to pull all of the things they learn into integrated, meaningful bodies of knowledge. Theorists have offered several suggestions for helping students learn science as integrated, cohesive theories and models:

• Introduce a new unit with a lesson or experiment that illustrates the important issues that the unit will address (science educators use the terms benchmark lesson and benchmark experiment).

• Use analogies that help students relate new ideas to prior knowledge.

• Present physical models of the phenomena being described, perhaps in the form of diagrams, flowcharts, or physical replicas.

• Ask students to organize the material they have learned (e.g., by drawing diagrams, making concept maps, or writing summaries).

• Have students reflect on and write about what they’ve observed and concluded. (A. L. Brown & Campione, 1994; D. E. Brown, 1992; Edens & Potter, 2001; Klein, 2000; Mayer, 1999; Mayer & Wittrock, 1996; Minstrell & Stimpson, 1996; Wittrock, 1994)
Revising Theories and Models

EXPERIENCING FIRSTHAND Water and Earth

Do these two problems before you read further.

1. A glass half full of water is lifted from the table on which it is resting and tilted at a 45-degree angle. Draw a line in the glass to mark the water’s surface.

2. A rock is dropped at the equator, at the entrances to two tunnels that go through the earth. Tunnel A comes out at the equator on the opposite side of the earth. Tunnel B comes out at the South Pole. Into which tunnel will the rock fall?

Your water line in the tilted glass should be parallel to the top of the table; in other words, it should be horizontal. Did you instead draw a line that slanted one way or the other? If so, you’re hardly alone; many adults have difficulty with this task (Pulos, 1997). I hope that you had an easier time with the “tunnels” question: The rock will fall into Tunnel A, toward the center of the earth.

Many middle school students have difficulty with both of these problems involving gravity. They draw a slanted line to indicate that the water’s surface tilts upward toward one side of the glass or the other, and they answer that the rock will fall into Tunnel B, thinking, apparently, that gravity always pulls something “down.” They respond in these ways despite many personal experiences with tilted water glasses and despite explicitly learning that gravity pulls objects toward the center of the earth (Pulos, 1997).

Just as scientific theories and models evolve over time as new evidence emerges, so, too, must our students continually revise their understanding of natural phenomena as they acquire more information; in other words, they must undergo conceptual change. Yet students often cling tenaciously to their naive ideas about scientific phenomena despite considerable experience and instruction to the contrary (diSessa, 1996; Keil & Silberstein, 1996; Reiner, Slotta, Chi, & Resnick, 2000; Vosniadou, 1991). (As an example, go to “Intuitive Physics” on the Simulations in Educational Psychology and Research CD that accompanies the textbook.)

Chapter 7 of the textbook identifies several strategies for promoting conceptual change. Following are additional strategies that relate specifically to science:
Supplementary Reading #8—Learning in the Content Areas

- Portray science as a dynamic, evolving collection of theories and models to be understood, rather than as a collection of discrete facts to be memorized.
- Identify and discuss students’ existing scientific beliefs (e.g., the idea that gravity pulls objects toward the South Pole), so that such beliefs are in working memory and, as a result, more likely to be modified.
- Relate abstract ideas to concrete and familiar experiences; for instance, illustrate the abstract concept density by showing how a can of diet soft drink floats in water while a can of regular soft drink sinks.
- Give students opportunities to discuss competing perspectives within a classroom environment that communicates the message, “It’s OK to make errors and to change our minds.” (Brandes, 1996; Byrnes, 1996; Duit, 1991; Keil & Silberstein, 1996; Minstrell & Stimpson, 1996)

At the same time, we must recognize that in some cases scientific explanations may be inconsistent with students’ personal belief systems; for instance, the theory of evolution may be inconsistent with the creationist views of a student’s religion. In such circumstances, our best approach may be to help students understand scientific explanations rather than convince them to accept these explanations as “truth” (Sinatra & Southerland, 2001; Southerland, Sinatra, & Matthews, 2001).

Applying Science to Real-World Problems

All too often, students have trouble relating the things they learn in science to real-world situations (Linn et al., 1996; Mayer, 1996). For instance, despite formal instruction about the nature of heat and insulation, it never occurs to many students that they can use wool to keep something cold as well as to keep it warm (Linn et al., 1996).

Ideally, any science curriculum should make frequent connections between school science and everyday situations (Linn et al., 1996; White & Frederiksen, 1998). Accordingly, we should provide numerous opportunities for students to apply scientific principles to the kinds of problems they are likely to encounter in their outside lives.

Metacognition

Students’ beliefs about the nature of science (i.e., their epistemological beliefs) will undoubtedly affect the approaches they take (mentally) when they study science. Students who believe that “knowing” science means understanding how various concepts and principles fit together and using those concepts and principles to explain everyday phenomena are going to study and learn more effectively than students who think that learning science means memorizing facts (Linn et al., 1996). Students who recognize that scientific theories will inevitably change over time are more likely to evaluate theories with a critical eye (Bereiter, 1994; Kuhn, 1993, 2001; Linn et al., 1996). Through both our lessons and our assessment techniques, we must continually communicate the message that “mastering” science means understanding concepts and principles in a meaningful fashion, integrating concepts and principles into a cohesive whole, revising personal theories in the light of new evidence, and applying science to real-world situations (Schauble, 1996; C. L. Smith, Maclin, Houghton, & Hennessey, 2000; Wittrock, 1994).

We can also promote metacognitive development in science by encouraging students to reflect on how they and their classmates are reasoning about scientific phenomena (Herrenkohl & Guerra, 1998; Palincsar & Herrenkohl, 1999; Van Meter, 2001). In one approach, which has been used effectively with fourth graders, students engage in short experiments and other activities in small groups. For each activity, they (a) make initial predictions and develop initial theories about what they think they will observe, (b) perform the activity and summarize their results, and (c) relate their
results to their initial predictions and theories. The students then meet as an entire class to present and evaluate each group’s findings and conclusions; at this time, some students act as “reporters” and others act as a critical audience, asking such questions as “What is your theory?” and “Did what you think was going to happen really happen?” Students who participate in such activities are more engaged in class, more likely to monitor their own understanding, and more likely to challenge one another’s explanations (Herrenkohl & Guerra, 1998; Palincsar & Herrenkohl, 1999).

Developmental Changes in Scientific Reasoning

As noted earlier, children acquire considerable knowledge about science long before they begin school. But their ability to think about science is apt to be limited throughout the elementary grades. As Chapter 2 in the textbook points out, abstract and hypothetical reasoning capabilities and the ability to separate and control variables all appear to be fairly limited until adolescence. Perhaps for this reason, elementary school teachers focus most science instruction on descriptions of natural phenomena rather than on explanations of why those phenomena occur (Byrnes, 1996). Yet even at the elementary level, it is probably counterproductive to portray science as primarily a collection of facts. By having students engage in simple experiments almost from the very beginning of the science curriculum, we convey the message that science is an ongoing, dynamic process of unraveling the mysteries of our world.

At the middle school level, students’ increasing ability to think about abstract ideas enables us to begin addressing some of the causal mechanisms that underlie natural phenomena. Yet even at this point, we may not want to introduce ideas completely removed from students’ everyday, concrete experiences (Linn & Muilenburg, 1996; Linn et al., 1996; Reiner et al., 2000). For instance, when teaching eighth graders about heat, we may have better success if we talk about heat as something that “flows” from one object to another rather than as something that involves molecules moving and colliding with one another at a certain rate. Although the heat-flow model is, from a chemical perspective, not entirely accurate, students can effectively apply it to a wide variety of everyday situations; for instance, they can use it to explain why a bathtub filled with warm water heats the air around it, why packing food in ice helps to keep it cold, and why using a wooden spoon is safer than using a metal one to stir something that’s cooking on the stove (Linn & Muilenburg, 1996).

When students reach high school, they are more likely to have acquired the scientific knowledge they need to begin thinking in truly abstract ways about natural phenomena (Linn et al., 1996). Nevertheless, we should continue to engage students in frequent hands-on science activities, not only through systematic laboratory experiments but also through informal, exploratory activities that relate scientific concepts and principles to everyday experiences. Secondary students in general, but especially females, are likely to achieve at higher levels when they have regular hands-on experiences with the phenomena they are studying (Burkam, Lee, & Smerdon, 1997).

General Strategies for Teaching Science

Throughout this section we have identified specific strategies for helping students learn various aspects of science more effectively. Following are three more general strategies to keep in mind:

- Engage students regularly in authentic scientific investigations. Historically, most science laboratory activities have been little more than cookbook recipes: Students are given specific materials and instructions to follow in a step-by-step manner (Committee on High School Biology Education, 1990). Although such activities can certainly help make scientific phenomena more concrete for students, they are unlikely to encourage students to engage in thinking processes—
INTO THE CLASSROOM: Promoting Mathematical and Scientific Reasoning Skills

• Take students’ cognitive development into account when teaching concepts and principles.
   A fourth-grade teacher asks his students to conduct experiments to find out what kinds of conditions influence the growth of sunflower seeds. He knows that his students probably have only a limited ability to separate and control variables, so he asks them to study the effects of just two things: the amount of water and the kind of soil. He has the students keep their growing plants on a shelf by the window, where temperature and amount of sunlight will be the same for all of the plants.

• Use concrete manipulatives and analogies to illustrate abstract ideas.
   A high school physics teacher has learned from experience that, even though her students are, in theory, capable of abstract thought, they are still likely to have trouble understanding this principle: *When an object rests on a surface, the object exerts a force on the surface, and the surface also exerts a force on the object.* To illustrate the principle, she places a book on a large spring. The book compresses the spring somewhat, but not completely. “So you see, class,” she says, “the book pushes downward on the spring, and the spring pushes upward on the book. An object compresses even a hard surface, such as a table, a little bit, and the surface pushes back up in response.” (based on D. E. Brown & Clement, 1989)

• Ask students to apply math and science to real-world problems.
   A third-grade teacher gives his students copies of a menu from a local family restaurant. He tells them, “Imagine that you have eight dollars to spend. Figure out what you might order for lunch so that your meal includes each of the food groups we’ve discussed.”

• Ask students to identify several strategies or hypotheses regarding a particular task or situation, and to explain and justify their ideas to one another.
   A middle school math teacher is beginning a unit on how to divide numbers by fractions. After students convene in small groups, she says, “You’ve already learned how to multiply one fraction by another. For example, you’ve learned that when you multiply 1/3 by 1/2, you get 1/6.

   But now imagine that you want to divide 1/3 by 1/2. Do you think you’ll get a number smaller than 1/3 or larger than 1/3? And what kind of number might you get? Discuss these questions within your groups. In a few minutes we’ll all get back together to talk about the ideas you’ve come up with.”

• Foster metacognitive strategies that students can use to regulate their experimentation and problem solving.
   When a high school science teacher has his students conduct lab experiments, he always has them keep several questions in mind as they work: (1) As I test the effects of one variable, am I controlling for possible effects of other variables? (2) Am I seeing anything that supports my hypothesis? (3) Am I seeing anything that contradicts my hypothesis?

• Have students use mathematics and scientific methods in other content domains.
   A junior high school social studies teacher asks his students to work in small groups to conduct experiments regarding the effects of smiling on other people’s behavior. As the groups design their experiments, he reminds them about the importance of separating and controlling variables, and he insists that each group identify an objective means of measuring the specific behavior or behaviors that it intends to study. Later, he has the groups tabulate their results and report their findings to the rest of the class.

Testing and formulating hypotheses, separating and controlling variables, and so on—that characterize true scientific reasoning (Keil & Silberstein, 1996; Padilla, 1991; Singer, Marx, Krajcik, & Chambers, 2000). So in addition, we must give students many opportunities to conduct investigations in which the procedures and outcomes are not necessarily predetermined. In some cases, we can provide materials that allow students to explore phenomena closely related to known
scientific principles; for instance, we might ask them to address questions such as “How does the amount of electric current affect electromagnetic strength?” or “How does temperature affect the germination rate of seeds?” (Padilla, 1991). In other situations, we can have students apply their developing experimentation skills to address everyday problems; for instance, we might pose a question such as “Does one fast food chain provide more meat in a hamburger than others?” or “Is one brand of paper towel stronger or more absorbent than the others?” (Padilla, 1991). We may also want to engage our students in long-term, outdoor field work, perhaps studying the quality of air in the local environment or analyzing the bacterial content of neighborhood rivers and lakes (Singer et al., 2000).

• Use class discussions to promote conceptual change. A growing body of research indicates that small-group and whole-class discussions help students acquire more accurate and integrated understandings of scientific phenomena—for many of the reasons that Chapter 7 in the textbook identifies (Bereiter, 1994; Greeno et al., 1996; Hatano & Inagaki, 1991; Minstrell & Stimpson, 1996; C. L. Smith et al., 2000). In the following essay, one sixth grader who has participated in an interactive, inquiry-oriented science curriculum throughout the elementary grades portrays science as the dynamic process that it truly is and explains how discussing science with peers has contributed to this epistemological belief:

I think science changes because people’s ideas change over time. This even happens in school science. For example, when someone tells you their ideas you may or may not understand it. However, if they change their explanation a little then you can understand it. Or when different people in a class explain their thinking about something we are all working on, soon different people in class begin to change their thinking and so do I. That’s how I develop my ideas. I discuss with other students and I listen to their explanations. I try to see things from their perspectives and they try to see things from me. All of us begin to develop ideas that are a combination of what we hear or discuss—that’s how I change my thinking. I think people who are scientists do the same thing. Only when they change their ideas or describe them from a different perspective then science itself changes. (C. L. Smith et al., 2000, p. 396)

• Make use of computer technology. Many software programs now enable students to explore scientific phenomena in ways that might not be possible in real life. Some programs let students “explore” human anatomy—the heart, the lungs, the eye, and so on—or conduct “dissections” of frogs, cats, and other species. Other programs create “virtual” environments that allow students to manipulate and experiment with such phenomena as friction, gravity, and thermodynamics, allowing them to separate and control variables in ways that the real world would prohibit (Greeno et al., 1996; Schauble, 1990; White & Frederiksen, 1998). Furthermore, electronic mail (e-mail) and the Internet provide means through which students can communicate with one another and with outside experts, enabling them to share information and test their hypotheses and ideas (Pea, 1992).

Over the past few decades, many psychologists and educators have studied how students learn mathematics and science and how teachers can help them master these content domains more effectively. Only recently, however, have a significant number of theorists and researchers turned their attention to that part of the school curriculum collectively known as social studies. In the next section we will explore some of the ideas that are beginning to emerge in this area.

Social Studies

Many theorists believe that the ultimate goal of social studies education should be to help students make informed decisions about matters of public policy, social welfare, and personal growth (Alleman & Brophy, 1997; Byrnes, 1996). In my own mind, social studies should also promote
tolerance for diverse perspectives and cultures, with the understanding that such diversity of ideas is essential for the social, moral, and cultural advancement of the human race over time.

If we want our students to draw on the things they learn in social studies when they make decisions as adult citizens, it is essential that we focus on meaningful learning and higher-level thinking skills—transfer, problem solving, and so on—in the social studies curriculum, rather than on the learning of discrete facts (Alleman & Brophy, 1997; Newmann, 1997). In this section we will consider how we might focus the curriculum in two specific areas: history and geography.

The Nature of Historical Knowledge and Thinking

A true understanding of history, both as a body of knowledge and as an academic discipline, requires several abilities and processes:

- Understanding the nature of historical time
- Drawing inferences from historical documents
- Identifying cause-effect relationships among events
- Recognizing that historical figures were real people

Understanding Historical Time

In the case study at the beginning of this reading, Ben accounts for America’s origins as follows:

2000 Days oh go George Washington gave us the Country to Live on.

As a second grader, Ben obviously has little sense of how long a time span “2000 days” is. Like Ben, children in the early elementary grades have little understanding of historical time (Barton & Levstik, 1996). For instance, they might refer to events that happened “a long, long time ago” or “in the old days” yet tell you that such events happened in 1999. And they tend to lump historical events into two general categories: those that happened very recently and those that happened many years ago. Not until about fifth grade do students show a reasonable ability to sequence historical events and to attach them to particular periods of time (Barton & Levstik, 1996).

Perhaps it is not surprising, then, that systematic history instruction typically does not begin until fifth grade (Byrnes, 1996). In the earlier grades, any instruction about history should probably focus on students’ own, personal histories and on events that have occurred locally and in the recent past (Byrnes, 1996).

Drawing Inferences from Historical Documents

History textbooks often describe historical events in a very matter-of-fact manner, communicating the message that “This is what actually happened” (Britt, Rouet, Georgi, & Perfetti, 1994; Paxton, 1999; Wineburg, 1994). In reality, however, historians often don’t know exactly how particular events occurred. Instead, they construct a reasonable interpretation of events after looking at a variety of historical documents that, in many cases, provide differing perspectives of what transpired (Leinhardt & Young, 1996; Seixas, 1996; Wineburg, 1994).

The idea that history is often as much a matter of perspective and opinion as it is a matter of fact is a fairly abstract notion that students may not be able to comprehend until they reach adolescence (Byrnes, 1996; Seixas, 1996). In the secondary grades, we can begin to have them read multiple accounts of significant historical events and then draw conclusions both about what definitely
happened and about what might have happened (Leinhardt, Beck, & Stainton, 1994; Paxton, 1999; Seixas, 1996). For instance, when students study racial strife in the American South, they might learn about the Montgomery, Alabama, bus boycott of 1955 both by reading newspaper articles published at the time and by reading Rosa Parks’ own account of why she refused to give up her bus seat for a white person (Banks, 1994). When they study the Mexican-American War, they should be exposed to the Mexican perspective as well as that of the United States. Ultimately, students at the secondary grade levels must discover that history is not as cut-and-dried as some present it—that learning history involves constructing a reasonable interpretation of events based on the evidence at hand and that some aspects of history may never be known for certain.

Identifying Cause-Effect Relationships Among Events

To some extent, an integrated knowledge of history includes an understanding of how some events led to others. For instance, it might be helpful for students to learn that economic hardship in the Southern states was a contributing factor to the Northern victory in the American Civil War and that paranoia about expanding empires was partly responsible for World War II, the Korean War, and the Vietnam War. One way we can help students learn such cause-effect relationships is, of course, is to describe them ourselves. But we can also engage students in discussions in which they develop their own explanations of why certain events may have occurred (Leinhardt, 1993). And we can indirectly help them discover causal relationships by asking them to consider how things might have been different if certain events had not taken place (Byrnes, 1996).

Thinking of Historical Figures as Real People

Students will learn historical events in a more meaningful fashion when they discover that historical figures had particular goals, motives, and personalities and that these individuals often had to make decisions based on incomplete information—in other words, that they were, in many respects, just ordinary human beings. For instance, we might ask students to read Rosa Parks’ explanation about why she refused to give up her bus seat for a white person:

People always say that I didn’t give up my seat because I was tired, but that isn’t true. I was not
tired physically, or no more tired than I usually was at the end of a working day. I was not old,
although some people have an image of me being old then. I was 42. No, the only tired I was, was
tired of giving in. (Parks, 1992, cited in Banks, 1994)

As another example, we might ask students to read newspaper accounts of World War II just prior to Harry Truman’s decision to drop an atomic bomb on Hiroshima—accounts that give students a better sense of what Truman probably did and did not know at the time (Yeager et al., 1997). Following are several additional strategies we can use to foster perspective taking:

• Assign works of fiction that realistically depict people living in particular times and places.
• Conduct a simulated legislative session or town meeting in which students debate the pros and cons of a particular course of action.
• Have “journalists” (two or three students) interview people (other students) who “participated” in various ways in a historical event.
• Role-play family discussions and decision making during critical times (e.g., British soldiers demand to be housed in American colonists’ homes, or a son wants to enlist and go off to war). (Brophy & Alleman, 1996; Brophy & VanSledright, 1997)

When students understand why historical figures behaved as they did, they are more likely to empathize with them, and such empathy makes historical events just that much more understandable (Seixas, 1996; Yeager et al., 1997).
The Nature of Geographic Knowledge and Thinking

Many people conceive of geography as consisting of little more than the locations of various countries, capital cities, rivers, and so on, perhaps because geography is often taught this way (Bochenhauer, 1990). In fact, the discipline of geography involves not only where things are but also why and how they got there (National Geographic Education Project, 1994). For instance, geographers study why and how rivers and mountain ranges end up where they do, why people are more likely to settle in some locations than in others, and how people in various locations interact with one another.

Mastering geography involves at least three things:

- Understanding maps as symbolic representations
- Identifying interrelationships among people, places, and environments
- Appreciating cultural differences

Understanding Maps as Symbolic Representations

Central to geographical thinking is the realization that maps depict the arrangement and characteristics of particular locations. Yet young children have trouble interpreting maps and using them effectively (Blades & Spencer, 1987; Liben & Downs, 1989b). Children in the early elementary grades don’t truly appreciate the symbolic nature of maps: They take what they see on a map too literally (Gardner, Torff, & Hatch, 1996; Liben & Downs, 1989b). For instance, they may think that roads depicted in red are paved with red concrete and that the lines separating states and countries are actually painted on the earth. Young children also have difficulty maintaining a sense of scale and proportion (Liben & Downs, 1989b). For instance, they might deny that a road could actually be a road because it’s “too skinny for two cars to fit on” or insist that mountains depicted on a three-dimensional relief map can’t possibly be mountains because “they aren’t high enough.”

One major goal of any geography curriculum, especially in the elementary grades, must be to foster an understanding of the symbolic nature of maps. Students probably need explicit instruction in map interpretation skills (Liben & Downs, 1989a). We can certainly do this by giving students practice in interpreting a wide variety of maps, including maps that depict different kinds of information (e.g., those that depict physical landforms, those that depict roads and highways, those that depict varying elevations) and maps that use different kinds of symbols (Liben & Downs, 1989a). We can also teach map interpretation skills by having students create their own maps, perhaps of their neighborhoods or even of the entire country (Forbes, Ormrod, Bernardi, Taylor, & Jackson, 1999; Gregg & Leinhardt, 1994a).

Students must learn, too, that different maps are drawn to different scales, reflecting various proportions between graphic representation and reality (Liben & Downs, 1989b). We must keep in mind that, because proportional reasoning typically does not emerge until adolescence (see Chapter 2 in the textbook), we probably do not want to study scale in any systematic way until the middle school years. At this point, we can specifically talk about the scales used in different maps (one inch per mile, one centimeter per ten kilometers, etc.).

Identifying Interrelationships Among People, Places, and Environments

Much of geography centers on principles that identify how people, places, and environments interact. Consider the following geographical principles as examples:
• People are more likely to settle in areas that are easily accessible—for instance, along navigable rivers or near major roadways.
• People tend to migrate from places with limited or decreasing resources to places with more plentiful resources.
• Historically, people who were separated by significant physical barriers—mountain ranges, large rivers, deserts, and so on—interacted with one another rarely, if at all, and so tended to develop different languages and cultures.

We can teach our students to use maps as tools not only to help them locate places but also to look for patterns in what they see and to speculate about why those patterns exist (Gregg & Leinhardt, 1994b; Liben & Downs, 1989a). For instance, we can ask them to consider questions such as these as they peruse maps like those in Figures 8.3 and 8.4:

• Why did Chicago become the major railroad center of the American Midwest in the middle of the nineteenth century? (Use Figure 8.3.)
• Why are the languages of the Far East so distinctly different from those of the Middle East? (Use Figure 8.4.)

Appreciating Cultural Differences

An important goal of any geography curriculum must be to help students develop an understanding and appreciation of cultural diversity. In Chapter 4 of the textbook, the section “Creating a More Multicultural Classroom Environment” identifies strategies for promoting cultural awareness and tolerance. Those strategies are probably worth repeating again in this context:

• Incorporate the values, beliefs, and traditions of many cultures into the curriculum.
• Work to break down ethnic and cultural stereotypes.
• Promote positive social interaction among students from various ethnic groups.
• Foster democratic ideals.

Although not all of these strategies fall within the discipline of geography, certainly they all fall within the more general domain of social studies.

An additional strategy is to show students that, despite superficial differences among cultures, human beings often behave in similar ways and for similar reasons. I found an excellent example of this strategy a few years ago when I visited Colorado’s Mesa Verde National Park, once the home of cliff-dwelling Native Americans now called the Anasazi (a Navajo word meaning “ancient ones”). The National Park Service distributed a pamphlet that compared the Anasazi lifestyle in the thirteenth century with that of people living in Europe during the same time period. Following are some excerpts from the pamphlet:

The romantic notion that the Middle Ages were filled with knights in shining armor and ladies-in-waiting is exaggerated. In reality, 80 to 90 percent of Europeans at that time were serfs or peasants. The thirteenth-century peasant was surrounded by a world just as difficult for him to understand as it was for the average Anasazi. In Europe famines, plagues and diseases were rampant and decimated populations almost overnight. . . . During a lunar eclipse, many Europeans might spend a night in terror behind their cottage walls of mud and wattle. It is no wonder that religion played a major role in the lives of both cultures, influencing a great deal of their daily activities. Given the problems of drought and overuse of natural resources, it is understandable that the Anasazi would seek outside assistance in the form of ceremonies and special rites, just as the Europeans were governed by their superstitious beliefs. In certain respects, the way the two cultures looked at their world was not so different at all.

. . . Sanitation was a major problem for both cultures. Today’s visitors [to Mesa Verde National Park] think it is appalling that the Anasazi would throw their refuse—broken pottery vessels, used sandals, food remnants, etc.—right out in front of the dwelling. However, European city dwellers threw their trash out their windows and onto the streets.... Since the humidity levels in the American Southwest are less than most areas of Europe, the stench and decay may have been worse in Europe than it was for the Anasazi. (Mesa Verde Museum Association, n.d.)

### Developmental Changes in Thinking About History and Geography

Students’ understanding of social studies is, of course, dependent on their growing cognitive abilities. At the elementary level, students tend to think in relatively concrete terms. For example, in history, they may conceptualize the birth of the United States as resulting from a single, specific event (e.g., the Boston Tea Party) or as involving nothing more than constructing new buildings and towns (Ormrod, Jackson, Kirby, Davis, & Benson, 1999). In geography, they may think that an airplane symbol on a map represents an airport with only one airplane (Liben & Downs, 1989b).

As students develop the ability to think abstractly, so, too, can they more readily comprehend the abstract principles that underlie historical events and geographical patterns. Furthermore, as they acquire an increasing ability to look at events from other people’s perspectives (see Chapter 3 in the textbook), they become more capable of empathizing with historical figures (Ormrod et al., 1999). And as they develop proportional reasoning, they can more effectively consider the concept of scale in map making.

### General Strategies for Teaching Social Studies

In addition to the specific strategies we’ve considered for teaching history and geography, following are three more general strategies for teaching social studies:
INTO THE CLASSROOM: Facilitating Learning in Social Studies

• Help students organize and integrate the things they are learning.
  During a unit on ancient civilizations (e.g., Mesopotamia, Egypt, Greece, Rome), a middle school teacher has her students mark the location of each civilization on a map of the Eastern Hemisphere. She also has them develop a time line that depicts the rise and fall of the various civilizations.

• Ask students to draw inferences.
  A geography teacher displays a map showing European countries and their capital cities. “Notice how almost all of the capital cities are located either by seaports or on major rivers,” he points out. “Why do you suppose that is?”

• Identify cause-effect relationships.
  A history teacher asks her students to consider the question, “What effects did the Japanese bombing of Pearl Harbor have on the course and final outcome of World War II?”

• Encourage empathy for people from diverse cultures and different periods of time.
  A fourth-grade teacher encourages his students to imagine themselves as Native Americans who are seeing Europeans for the first time. “You see some strange-looking men sail to shore on big boats—boats much larger than the canoes your own people use. As the men disembark from their boats and approach your village, you see that they have very light skin; in fact, it is almost white. Furthermore, some of them have yellow hair and blue eyes. ‘Funny colors for hair and eyes,’ you think to yourself. How might you feel as these people approach?”

• Choose content that helps students discover important principles and ideas within the discipline.
  Social studies cover a broad range of topics—far too many to include in just twelve or thirteen years of schooling. So what exactly do we include in a social studies curriculum? Theorists suggest that we develop lessons and units that help students discover the key principles—the “big ideas”—that underlie social studies (Alleman & Brophy, 1997; Newmann, 1988; Olsen, 1995). For instance, when teaching students about various wars, we might focus on cause-effect relationships and general trends (e.g., the role of women on the home front and in the military) rather than on the details of specific battles (Olsen, 1995). Or, when exploring the geography of Africa, we might consider how different environments (tropical rain forests, desert plains, etc.) lead to very different lifestyles among the residents of various regions.

• Determine what students do and do not already know about a new topic.
  Many history textbook writers assume their readers have knowledge that the students probably don’t have (Beck, McKeown, & Gromoll, 1989; McKeown & Beck, 1994). For instance, textbook writers may assume that fifth graders can appreciate why the early American colonists resented the British policy of “taxation without representation,” yet such a situation is far removed from students’ own personal experiences. In the history compositions previously presented in this supplementary reading, we saw numerous errors of fact—errors that might easily lead to confusion as students study history in later grades. For example, one second grader in the opening case study believed that the dinosaurs were around as recently as six thousand years ago. And the eighth grader whose composition appeared in the “What’s Wrong?” exercise didn’t know that Britain and Brittany are different places. When we begin with what our students definitely know, not with what we think they should know, and proceed from there, our students’ comprehension of social studies will almost certainly improve (Brophy & VanSledright, 1997; McKeown & Beck, 1994).

• Have students conduct their own research using primary source materials.
  Our students must eventually learn that history and geography are, like science, evolving disciplines and that, even as
students, they can contribute to the knowledge bases in these disciplines. For instance, we might have them study the history of their own community using old newspapers, brochures, personal letters, and other artifacts; they can then display their findings in a local museum (A. Collins, Hawkins, & Carver, 1991). Or we might have them compile data about the populations of people living in various parts of their state, province, or country (perhaps voting records, occupations, or frequency of various health problems) and then construct maps that depict patterns in these data.

As you have seen, each of the content domains we’ve considered—reading, writing, mathematics, science, and social studies—involves numerous skills and abilities that are somewhat domain-specific. Accordingly, different teaching strategies may be more or less applicable for each of them.

Before we close, we should consider how we can accommodate student diversity as we teach various content areas. Then, as we look at the “Big Picture,” we will revisit the five general principles we identified at the beginning of the chapter.

Taking Student Diversity into Account

As we teach reading and writing, we must remember that students’ early experiences with language and literature are likely to vary considerably. For instance, students in some African American families may have had few experiences reading storybooks but a great deal of experience with storytelling, jokes, rhymes, and other creative forms of oral language (Trawick-Smith, 2000). Some Native American communities may value nonlinguistic forms of expression, such as art and dancing, more than reading and writing (Trawick-Smith, 2000). We must be sensitive to what students’ early language and literacy experiences have been and use the specific knowledge and skills that they have developed as the basis for future instruction in reading and writing. For instance, students who can use their local dialect when they write stories may write more imaginatively than students who must use standard English (Smitherman, 1994).

When teaching mathematics and science, we must keep in mind that these two disciplines have, historically, been considered “male” domains. As a result, the boys in our classes are more likely to believe that they can be successful in these areas; this will be the case even though there are no substantial gender differences in ability in these areas (see Chapter 4 in the textbook). We must make a concerted effort to convey the message that mathematics and science are important for girls as well as boys. We should also use instructional strategies—small-group discussions, hands-on activities, cooperative learning, and so on—that encourage males and females alike to become actively involved in studying, talking about, and mastering math and science.

As we teach social studies, we must remember that students’ perspectives on history and geography will, in part, be a function of the cultures in which they have been raised and the early family experiences they have had. For instance, a student with a Japanese heritage is likely to have a very different perspective on Truman’s decision to bomb Hiroshima than a student with English ancestors. Students who have traveled extensively are apt to have a greater appreciation of distance, a greater knowledge of differing environmental landscapes, and a better understanding of how maps are used (Trawick-Smith, 2000). A friend of mine once described her experience taking children raised in a lower-income, inner-city Denver neighborhood on a field trip into the Rocky Mountains. Even though these children had seen the Rockies many times from downtown Denver, some of them, upon seeing the mountains up close for the very first time, were amazed at how big they were. And a few children were quite surprised to discover that the white stuff on the mountaintops was snow!
Accommodating Students with Special Needs

Many students with special needs have difficulty with reading and writing. The majority of poor readers, whether they’ve been identified as having a learning disability, attention-deficit hyperactivity disorder (ADHD), or some other disability, appear to have a significant deficit in phonological awareness: They have difficulty hearing the individual sounds in words and connecting those sounds with letters (Hulme & Joshi, 1998; Morris et al., 1998; Stanovich, 2000; Swanson, Mink, & Bocian, 1999). A few poor readers have other cognitive processing deficits; for example, they may have greater-than-average difficulty retrieving words and word meanings based on what they see on the page (Stanovich, 2000). Such difficulties with literacy can have wide-ranging effects, not only for achievement in other disciplines but also for self-esteem. Tom, a second grader, describes his feelings when first trying to learn how to read in first grade:

I felt like a loser. Like nobody liked me. I was afraid that kids would tease me. Because I wasn’t learning well ... I did not want to read. I would want to throw a book at my mom. (Knapp, 1995, p. 9)

Students’ difficulties are not always limited to reading and writing, of course; for instance, some students with learning disabilities have difficulty with mathematics as well (Cawley & Miller, 1989). So when we teach various content domains, we must often make special accommodations for those students who have special educational needs. Table 8.2 presents some specific strategies that may be helpful as we work with these students.

The Big Picture

In this final section we summarize what we’ve learned about each of the content areas. We then revisit the five general principles identified at the beginning of the chapter.

Reading

Most children learn some things about literacy (e.g., that particular words are always spelled in the same way) before they begin school; such knowledge is called emergent literacy. Skilled reading involves knowing letter-sound correspondences, recognizing both individual letters and entire words quickly and automatically, using context clues to facilitate decoding, constructing meaning from the words on the page, and metacognitively regulating the reading process. Strategies for helping students become proficient readers include promoting phonological awareness, scaffolding students’ efforts to make sense of what they read, giving students many opportunities to read authentic literature, and engaging students in discussions about what they are reading.

Writing

Skilled writing involves planning, drafting, metacognition, and revision, and good writers move back and forth flexibly among these processes. We can help students learn to write effectively by asking them to clarify their goals for writing and the audience for whom they are writing, to organize their thoughts before they begin to write, and to focus more on clear communication than on writing mechanics in early drafts. We should also assign writing tasks in all areas of the curriculum and provide sufficient criteria and feedback to guide students as they revise what they’ve written.
### Table 8.2. Helping Students with Special Needs Achieve in Various Content Domains

<table>
<thead>
<tr>
<th>Category</th>
<th>Characteristics You Might Observe</th>
<th>Suggested Classroom Strategies</th>
</tr>
</thead>
</table>
| Students with specific cognitive or academic difficulties | Difficulties in word recognition and reading comprehension, often as a result of poor phonological awareness  
Difficulties in spelling and handwriting  
Tendency to focus on mechanics (rather than meaning) during the revision stage of writing  
Less developed writing skills (if students have learning disabilities)  
Greater than average difficulty learning basic facts in math, science, and social studies | Assign reading materials appropriate for students’ reading skills.  
Provide extra scaffolding for reading assignments (e.g., shorten assignments, identify main ideas, have students look for answers to specific questions).  
Provide extra scaffolding for writing activities (e.g., ask students to set goals for their writing, give students a specific structure to follow as they write, encourage use of word processing programs with grammar and spell checkers).  
Use concrete manipulatives to teach math and science.  
Use mnemonics to help students remember basic facts. |
| Students with social or behavioral problems | Less motivation to achieve academic success in some or all content domains  
In some instances, achievement two or more years below grade level in one or more content domains | Have students read and write about topics of personal interest.  
Ask students to apply math, science, and social studies to situations relevant to their own lives. (Also use strategies listed for students with specific cognitive or academic difficulties.) |
| Students with general delays in cognitive and social functioning | Delayed language development (e.g., in reading, writing)  
Less developed knowledge base to which new information can be related  
Difficulty remembering basic facts  
Lack of learning strategies such as rehearsal or organization  
Reasoning abilities characteristic of younger children (e.g., inability to think abstractly in the secondary grades) | Minimize reliance on reading materials as a way of presenting new information.  
Provide experiences that help students learn the basic knowledge and skills that other students may have already learned on their own.  
Have students conduct simple scientific experiments in which they need to consider only one or two variables at a time. (Also use strategies listed for students with specific cognitive or academic difficulties.) |
| Students with physical or sensory challenges | More limited reading and writing skills, especially if students have hearing loss  
Less awareness of the conventions of written language, especially if students have visual impairments  
Fewer outside experiences and less general world knowledge upon which instruction in math, science, and social studies can build | Locate Braille texts for students with visual impairments.  
When students have difficulty with motor coordination, allow them to dictate the things that they write.  
Conduct demonstrations and experiments to illustrate basic scientific concepts and principles.  
Use drama and role playing to illustrate historical events.  
If students have visual impairments, use three-dimensional relief maps and embellish two-dimensional maps with dried glue or nail polish. |
| Students with advanced cognitive development | Development of reading at an early age  
Advanced reading comprehension ability  
More sophisticated writing abilities  
Greater ability to construct abstract and integrated understandings | Provide challenging tasks (e.g., higher-level reading assignments, more advanced writing assignments).  
Form study groups in which students can pursue advanced topics in particular domains. |

Mathematics

To master mathematics, students must understand key mathematical concepts and principles, encode problems in ways that facilitate correct solutions, relate problem-solving procedures to the mathematical concepts and principles that underlie them, and acquire appropriate metacognitive processes and beliefs. We can facilitate students’ mathematics learning by using concrete situations to illustrate abstract concepts, promoting automaticity in basic facts and skills, giving students a great deal of practice solving a wide variety of problems, and teaching students how to monitor their problem-solving efforts.

Science

Scientific reasoning involves investigating natural phenomena objectively and systematically, constructing theories and models that explain these phenomena, revising those theories and models in light of new evidence or better explanations, and metacognitively overseeing the reasoning process. We can help students learn science and scientific methods by scaffolding their efforts to conduct meaningful and authentic investigations, encouraging them to learn how scientific concepts and principles are interconnected and related to everyday situations, and engaging them in discussions about their hypotheses and predictions.

Social Studies

Effective learning in history involves understanding the nature of historical time, drawing inferences from historical documents, identifying causal relationships among events, and recognizing that historical figures were real people. Effective learning in geography involves understanding that maps are symbolic representations of places, identifying interrelationships among people and their environments, and appreciating cultural differences. When we teach social studies, we should choose topics that encompass important general principles, point out cause-effect relationships, identify similarities among diverse cultures, and have students conduct some their own research.

Revisiting the Five General Principles

Although the various domains considered in this chapter involve cognitive processes that are, to some degree, quite specific to those content areas, many general principles of learning and development (e.g., the importance of meaningful learning and elaboration, the increase in abstract thinking over time) kept popping up in our discussion. Five principles, summarized in Table 8.3, have been especially prominent:

- **Learners use the information they receive from various sources to build their own, unique understandings of the world.** We’ve seen this principle at work in how students construct meaning from what they read, engage in knowledge transforming as they write, and build increasingly complex and integrated understandings as they study mathematics, science, and social studies.

- **Learners’ interpretations of new information and events are influenced by what they already know and believe about the world.** Students draw on their prior knowledge to interpret what they read, and they write more effectively about the things they know well. Their success in learning mathematics depends on how well they’ve mastered prerequisite concepts and procedures. Their ability to learn and apply scientific principles is influenced by their personal theories about scientific phenomena. Their understanding of social studies is enhanced when they relate historical events and geographical phenomena to their personal experiences.
### Table 8.3. Applying Five General Principles in Different Content Domains

<table>
<thead>
<tr>
<th>Principle</th>
<th>Reading</th>
<th>Writing</th>
<th>Mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructive processes</td>
<td>Students construct an understanding of an author’s intended meaning using the clues that the text provides. Good readers go beyond the specific things that they read, drawing inferences, making predictions, finding symbolism, and so on.</td>
<td>Effective writing is a process of knowledge transforming rather than knowledge telling.</td>
<td>Beginning with a basic understanding of numbers and counting, students build an increasingly complex and integrated understanding of mathematical concepts and principles.</td>
</tr>
<tr>
<td>Influence of prior knowledge</td>
<td>Students use what they already know about a topic to help them construct meaning from text. Their knowledge of typical text structures (e.g., the usual sequence of events of stories, the usual structure of expository text) also assists them in comprehension.</td>
<td>Students write more effectively about things that they know well.</td>
<td>Mathematics is an especially hierarchical discipline—one in which advanced concepts and principles almost always build on ideas learned in earlier years.</td>
</tr>
<tr>
<td>Role of metacognition</td>
<td>Good readers monitor their comprehension and engage in processes that are likely to increase their comprehension (setting goals, asking questions that they try to answer, etc.).</td>
<td>Good writers set goals for their writing, consider what their audience is likely to know about their topic, and think consciously about how to help the audience understand the message they are trying to communicate.</td>
<td>Effective problem solvers monitor their progress toward problem solutions. They also have epistemological beliefs conducive to problem-solving success; for instance, they recognize that mathematical procedures make logical sense and know that they may need to try several different approaches before they are successful.</td>
</tr>
<tr>
<td>Qualitative changes with development</td>
<td>In the preschool and early elementary years, students begin to develop and use word decoding skills, and they are capable of comprehending simple text. At the upper elementary grades, word recognition is largely automatic, enabling students to focus almost exclusively on comprehension. In the secondary years, students acquire more sophisticated metacognitive skills and become more critical of what they read.</td>
<td>Young writers have difficulty writing for an imaginary audience and engage almost exclusively in knowledge telling. As writing mechanics become more automatic in the upper elementary grades, students begin to use complex sentence structures and to focus on communicating effectively. Secondary school students produce more comprehensive and organized texts, and some (but not all) of them engage in knowledge transforming.</td>
<td>In the elementary grades, students’ understanding of mathematics is limited to concrete situations and focuses on simple operations (e.g., addition, multiplication). In the middle and secondary school years, students become increasingly able to think about abstract concepts and procedures (e.g., solving for an unknown ( x ) in algebra).</td>
</tr>
<tr>
<td>Social interaction</td>
<td>Students more effectively construct meaning from what they read when they discuss their readings with their classmates.</td>
<td>Students write more effectively when their peers read and critique their work and when they collaborate on writing projects.</td>
<td>Students gain a better understanding of math when they tutor classmates or younger students. They gain greater metacognitive awareness of their strategies, and they may also modify inappropriate ones, when they must explain and justify their reasoning to others.</td>
</tr>
</tbody>
</table>
Table 8.3 (continued)

<table>
<thead>
<tr>
<th>Principle</th>
<th>Science</th>
<th>Social Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constructive</strong></td>
<td>Learning science effectively involves constructing an integrated understanding of concepts and principles related to a particular topic.</td>
<td>Mastery of history and geography involves constructing integrated understandings of cause-effect relationships.</td>
</tr>
<tr>
<td><strong>Influence of</strong></td>
<td>Students often develop personal theories about natural phenomena long before they have formal instruction about these phenomena. To the extent that such theories represent inaccurate understandings, they may interfere with students’ ability to learn more scientifically acceptable explanations.</td>
<td>Students learn social studies more effectively when they can relate historical events and geographical phenomena to their own personal experiences.</td>
</tr>
<tr>
<td><strong>Role of</strong></td>
<td>Students’ beliefs about what science is influence how they study and learn science; for instance, those who believe that science consists of isolated facts are likely to focus on meaningless memorization. Furthermore, students’ ability to conduct meaningful experiments is influenced by the extent to which they ask themselves questions about their observations and interpretations (e.g., “Have I confirmed my prediction?”).</td>
<td>A true understanding of history involves the recognition that a great deal of historical “knowledge” is interpretive rather than factual.</td>
</tr>
<tr>
<td><strong>Qualitative</strong></td>
<td>In the elementary grades, students have difficulty thinking about abstract scientific concepts, and they can separate and control variables only in simple and familiar situations. In the middle school grades, students still have limited abstract reasoning capabilities and so may benefit from concrete models of scientific phenomena (e.g., the idea of heat “flow”). High school students can comprehend abstract scientific explanations, especially after they have studied a topic in depth.</td>
<td>Elementary school students (especially those in the lower grades) have difficulty comprehending the nature of historical time and appreciating the symbolic nature of maps. At the secondary level, students’ understanding of both history and geography becomes increasingly abstract. Secondary students are more capable of empathizing with historical figures; in addition, they can apply their proportional reasoning skills to interpreting the scales of various maps.</td>
</tr>
<tr>
<td><strong>Social</strong></td>
<td>Students revise misconceptions about scientific phenomena and acquire more sophisticated scientific reasoning processes when they jointly wrestle with puzzling findings and critique one another’s conclusions.</td>
<td>Students can better appreciate the perspectives of historical figures when they role-play historical events.</td>
</tr>
</tbody>
</table>

**Influence of prior knowledge**
• Over time, learners develop cognitive strategies and epistemological beliefs that influence their thinking and performance within a particular content domain. Good readers, writers, mathematicians, and scientists continually monitor their progress toward goals and ask themselves questions that guide their thinking. Furthermore, certain epistemological beliefs—for example, beliefs that mathematical procedures make logical sense and that much of history is interpretive rather than factual—increase the likelihood that students will learn and achieve at high levels.

• The ways in which learners think about and understand academic subject matter are qualitatively different at different points in their cognitive development. Several trends in cognitive development influence students’ learning and performance in the content domains, including the increasing automaticity of basic skills and growing ability to think abstractly, separate and control variables, reason about proportions, and take the perspectives of others.

• Learners often gain greater understanding and greater metacognitive sophistication in a subject area when they work collaboratively with their peers. Throughout the chapter we’ve repeatedly seen the benefits of having students work together. Small-group and whole-class discussions help students construct meaning from what they read in fiction and textbooks and from what they observe in scientific investigations. Students who work together create better written compositions and can tackle more challenging mathematical problems. When students must justify their actions to someone else, they develop greater awareness of their reasoning and problem-solving processes. And when they role-play historical events, they gain a better appreciation of the very “human” nature of historical figures.

Case Study: All Charged Up

Jean, Greg, Jack, and Julie are working on a laboratory assignment in Mr. Hammer’s high school physics class. They are using a ball of crumpled aluminum hanging from a piece of string (a device known as a pith ball) to determine whether various objects have an electric charge; objects that are charged will make the aluminum ball swing either toward or away from them, and objects that aren’t charged will have no effect on the ball. The students have attached two plastic straws—one wrapped in aluminum foil—to opposite sides of an aluminum pie plate, which they have placed on a Styrofoam cup. The materials before them look like this:

The students put a charge on the aluminum pie plate and discover that the aluminum-covered straw becomes electrically charged (it attracts the pith ball), but the uncovered plastic straw remains uncharged. As Mr. Hammer approaches, Greg explains what the group thinks it has just observed:

Greg: The plate is aluminum, right? And the foil-covered straw is the same thing. The plate charges the foil straw because they’re both aluminum.

Mr. H.:Hmmm . . . do you think that if the plate were plastic, then the plastic straw would become charged?

Greg: If the plate was charged and if it was plastic, then yes.

Mr. H.:So your idea is that one object can charge another only if both objects are made of the same kind of material—that aluminum charges aluminum, and plastic charges plastic?

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Greg agrees with Mr. Hammer’s statement, as do Julie and Jack. Jean is hesitant, however, and suggests another experiment.

Jean: I don’t know, could we try it with the foam? Charge a foam plate, maybe, and then put a foam cup on it.

Mr. H.: That’s a great experiment.

Mr. Hammer is delighted. He knows that Styrofoam does not conduct electricity, so a foam plate cannot possibly share a charge with a foam cup. He fully expects that the experiment Jean has proposed will force the students to discard their hypothesis that any object can be charged but will transfer its charge only to other objects of the same material (in reality, some materials can be charged but others cannot). He gives the group a couple of foam plates to add to their experimental materials and then moves on to converse with other students.

Later in the lab session, Mr. Hammer returns to the foursome to inquire about their observations in the second experiment. He is quite taken aback at what they tell him.

Jack: It worked. The charge on the foam plate spread to the foam cup.

Julie: We even tried it in a different way. We put one foam plate on top of another one, and it gave us the same result.

All four students are quite confident about the conclusion they have drawn from their experiments: Charge moves from foam to foam in the same way that it moves from aluminum to aluminum.

(based on Hammer, 1997, p. 486)

- Why do the students draw an erroneous conclusion from their experiments with the foam objects? What common error in scientific reasoning are they making?

- What strategies might Mr. Hammer use to encourage the students to reject their current hypothesis and adopt one more consistent with the laws of physics?

Once you have answered these questions, compare your responses with those presented following the Glossary for this Study Guide and Reader.

Using the Student Artifact Library

You can find many examples of actual classroom assignments and students’ work in language arts, mathematics, science, and social studies on the Companion Website for Educational Psychology: Developing Learners. You can find this site at http://www.prenhall.com/ormrod. Once you’re there, click on the “Student Artifact Library” module on the navigation bar on the left side of the screen.