Chapter 11

TEACHING SPECIFIC TYPES OF KNOWLEDGE

In general, the nine categories of instructional strategies described in Chapters 2 through 10 work well with all types of subject-matter knowledge. However, if a teacher wishes, she can use specific instructional strategies to teach specific types of knowledge.

Subject-matter knowledge can be organized into five broad categories: (1) vocabulary terms and phrases, (2) details, (3) organizing ideas, (4) skills and tactics, and (5) processes. The first three categories are informational in nature and are sometimes referred to as *declarative knowledge*. The last two categories are more process oriented and are sometimes referred to as *procedural knowledge*.

VOCABULARY TERMS AND PHRASES

1. Directly Teach Critical Terms and Phrases.
(See Illustration 1)

Direct instruction has a strong influence on student achievement. Given this effect, one obvious instructional activity is to identify terms and phrases that are critical to a topic and directly teach those terms and phrases. It is probably best to limit the number of critical terms and phrases for any given topic. For example, a teacher presenting a three-week unit on a specific topic might identify five key terms and phrases related to that topic. The most straightforward way to directly teach new terms and phrases is to provide students with a definition of each term or phrase and a brief illustration of its use in context, as exemplified by Illustration 1.

2. Actively Engage Students in Learning New Terms and Phrases.
(See Illustration 2)

Perhaps the most powerful way to teach new terms and phrases is to actively involve students in the learning process, as shown in Illustration 2. The following five-step process for teaching vocabulary exposes students to new terms and phrases multiple times in a variety of ways:

Step 1. Give students a brief explanation or description of the new term or phrase.
Step 2. Present students with a nonlinguistic representation of the new term or phrase.
Step 3. Ask students to generate their own explanations or descriptions of the term or phrase.
Step 4. Ask students to create their own nonlinguistic representation of the term or phrase.
Step 5. Periodically ask students to review the accuracy of their explanations and representations.

Illustration 1: Directly Teach Terms and Phrases *geography*

Students in Mr. Mifflin's class were studying about the characteristics and uses of maps, globes, and other geographic tools and technologies. In planning the unit, Mr. Mifflin identified a number of vocabulary terms that he considered important for students to learn: *axis*, *meridian*, *latitude*, *longitude*, *prime meridian*, and *international date line*.

Mr. Mifflin gave students a handout he had created that included the terms, a definition of each term, and a sentence that used each term in context. For example, for the term *international date line*, Mr. Mifflin gave students the following information:

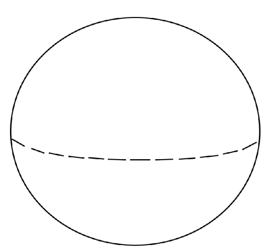
> *International date line*: an imaginary line approximately along the 180th meridian designated as the place where each calendar day begins. The date in the Eastern hemisphere, to the left of the line, is always one day ahead of the date in the Western hemisphere.
>
> *Example:* A ship traveling west from the western coast of the United States to Australia would cross the international date line and be one day ahead of when it left its port.

ILLUSTRATION 2: ENGAGE STUDENTS IN LEARNING NEW TERMS AND PHRASES *equator*

During the same geography unit, Mr. Mifflin decided to actively engage students in the process of learning the term *equator* using the five-step vocabulary process.

Step 1. Give students a brief explanation or description of the new term or phrase. He introduced students to the term by briefly explaining what the equator is: "The equator is an imaginary circle around the Earth that divides the Earth into the northern hemisphere and the southern hemisphere."

Step 2. Present students with a nonlinguistic representation of the new term or phrase. Mr. Mifflin then drew the following picture on the board:



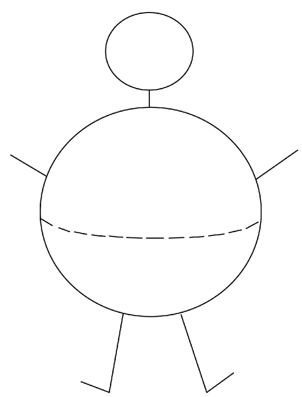
(Illustration continued on next page.)

ILLUSTRATION 2 *(continued)*

Then he asked students to gather around a table in the room. He held up an orange that had a black line drawn around the fattest part. He told students to imagine that the orange was the Earth and the black line was the equator. Then he cut the orange in half on the black line, explaining that the word *equator* contains a clue about what the word means. He asked if anyone knew what that might be. A couple of students said that it was like the word *equal* — the two halves of the Earth are equal on either side of the equator.

Step 3. Ask students to generate their own explanations or descriptions of the term or phrase. Mr. Mifflin's students then made up their own explanations of the term *equator*. Jake wrote in his vocabulary notebook, "The equator is what divides the Earth in half around its waist."

Step 4. Ask students to create their own nonlinguistic representation of the term or phrase. Each student then created a drawing or symbol for the term *equator*. Jake thought he could remember that the equator "cut the Earth in half." But he thought he might forget which direction it cut around the Earth, so he drew the following picture, which was similar to Mr. Mifflin's, but had some important differences.



Step 5. Periodically ask students to review the accuracy of their explanations and representations. Over the next few days, Mr. Mifflin involved the students in a number of activities he had planned for the unit. At the end of the week, he set aside some time for students to review the definitions and nonlinguistic representations in their notebooks. Some students made corrections or expanded on their definitions to reflect their increased understanding of the terms.

DETAILS

1. Expose Students to Key Details Multiple Times.
(See Illustration 1)

During a unit of instruction, students are exposed to a wide variety of details: facts, time sequences, and so on. Certainly they cannot process all of this information at a deep enough level to remember and use it at a later date. Consequently, a sound instructional strategy is to plan a unit in such a way that key details are identified — details that students are expected to know in depth, as exemplified by Illustration 1. In addition, instruction should be planned in such a way that students are exposed to these details multiple times (at least three) and that these exposures are no more than two days apart.

2. Engage Students in Enactment or Dramatic Representation of Key Details.
(See Illustration 2)

Given the impact on student learning of instruction that involves some form of enactment or dramatic representation of details, instruction should be planned to ensure that it occurs, as exemplified by Illustration 2.

ILLUSTRATION 1: MULTIPLE EXPOSURES TO DETAILS *Greek and Roman mythology*

Ms. Sanders' class at Dry Creek Middle School was beginning a unit on Greek and Roman Mythology. As she planned the unit, Ms. Sanders identified the critical aspects of the unit and the ways in which she would expose the class to these details several different times. She decided she wanted the class to know about significant gods and goddesses and what they represent. She also wanted to expose students to certain key myths and to have them notice how gods, goddesses, and humans interact in the myths.

On the first day of the unit, Ms. Sanders read aloud a myth and engaged the class in a discussion in which she introduced significant gods and goddesses by their Greek and Roman names, talked about their attributes, and showed the class a picture of each. The next day the class watched a film about early Greek architecture, which included numerous examples of the gods and goddesses and the stories that are depicted on early Greek buildings. Ms. Sanders assigned reading about the Trojan War as homework.

Later that week, Ms. Sanders divided the class into small groups of two to three students. She assigned each group a particular god or goddess and had them design a hat that symbolized the god or goddess's attributes. Students presented their hats to the class and explained their meaning.

ILLUSTRATION 2: ENACTMENT *biology — the lungs*

Ms. Siegel's biology class was finishing a unit on the organ systems of the human body. Many students performed poorly on the quiz about how oxygen and carbon dioxide are exchanged in the lungs, even though they had been exposed to the information multiple times. Ms. Siegel decided to try a technique that works well with details — dramatic representation. She told students they were going to act out the process of oxygen leaving the lungs and moving around the body and carbon dioxide being taken from body cells and removed through the lungs.

Students organized themselves into various roles, including lungs, alveoli sacs, red blood cells, plasma, and body cells. They used plastic models of molecules to represent the oxygen and carbon dioxide. Students traded molecules to show the exchange as red blood cells and plasma moved out of the lungs and around the circulatory system, represented by the "body cell" students. At first, many students thought the dramatization was silly, but after they took their unit test, they realized that the enactment had really helped them understand the process.

ORGANIZING IDEAS

1. *Provide Clear Statements of Generalizations and Numerous Examples.*
(See Illustration 1)

Generalizations and principles are complex enough that teachers should ensure that students are provided with clear statements and examples, as shown in Illustration 1.

2. *Help Students Increase Their Understanding of Generalizations and Principles and Clear up Misconceptions.*
(See Illustration 2)

When students have apparent misconceptions about organizing ideas, the teacher might present examples that help them understand the flaws in their thinking. If students seem to understand the generalizations accurately, but not in depth, the teacher might present a novel situation in which the generalization would apply. The teacher also might ask students to come up with new examples or situations in which the principle applies, as exemplified by Illustration 2.

ILLUSTRATION 1: PROVIDE GENERALIZATION AND EXAMPLES *fairy tales*

Students in Mrs. Brown's class were studying fairy tales and other types of children's literature. To deepen their understanding about the common themes found in fairy tales, Mrs. Brown gave students the following generalization: "Most fairy tales have a beautiful young girl as a major character who is in peril but eventually saved." Mrs. Brown then provided students with several examples:

Little Red Riding Hood — A woodcutter's daughter goes to visit her grandmother, is attacked by a wolf, but saved by a woodsman.

Sleeping Beauty — A beautiful daughter is born to a king and queen, but a wicked woman casts a spell on her. She is eventually saved by the kiss of a prince.

Cinderella — A beautiful girl is mistreated by her ugly step-sisters and cruel step-mother. She is whisked away to a ball by a fairy godmother where the handsome young prince falls in love with her and marries her.

Rapunzel — A beautiful child is locked in a tall tower by a wicked witch. A prince falls in love with her and tries to rescue her. Rapunzel is taken to a desert by the witch, but the prince finds her and takes her away to his kingdom.

Mrs. Brown then asked students class to think of other examples that exemplify the generalization about fairy tales.

ILLUSTRATION 2: INCREASE UNDERSTANDING & CLEAR UP MISCONCEPTIONS *properties of metals*

When grading lab reports, Mrs. Walton, an eighth grade science teacher, noticed that her students had some misconceptions about the properties of metals. For example, some of them thought that metals shrank when exposed to heat. To help clear up their misconceptions, Mrs. Walton wrote the following principle on the blackboard:

> *"When metals are heated, they expand. The magnitude of the expansion depends on the properties of the metal."*

Then Mrs. Walton demonstrated the effects of heat on aluminum by first measuring a cylinder of aluminum with a caliper and then heating the cylinder in a beaker of boiling water for several minutes. When she removed the aluminum cylinder, she asked a student to

(Illustration continued on next page.)

ILLUSTRATION 2 *(continued)*

quickly try to slip the cylinder back into the caliper without readjusting it. Students observed that the heat caused the aluminum to expand.

To further increase their understanding of the principle that metals expand when heated, the class discussed some facts about other metals:

Lead expands at 28.9 parts per million for every degree centigrade of temperature change.

Copper expands at 16.5 parts per million for every degree centigrade of temperature change.

Mrs. Walton asked students to create a graph showing the relationship between temperature and expansion for aluminum, lead, and copper. Then she asked students to choose two other metals, research the rate of expansion for each metal, graph the relationship between the rate of expansion and temperature, and explain how the principle applied to each metal. Finally, she led a class discussion in which students talked about previous misconceptions that they had, explained how the task helped clarify these, and asked any remaining questions.

SKILLS AND TACTICS

1. Facilitate the Discovery Approach to Skills.
(See Illustration 1)

When a discovery approach is used to teach a specific skill or tactic, examples should be organized so that different types of strategies are represented. As students progress through each category of examples, they should be asked to design strategies for the examples, as exemplified by Illustration 1. When students have worked through the examples, they might also be asked to contrast the strategies developed for the different categories.

2. Plan for and Emphasize the Importance of Distributed Practice.
(See Illustration 2)

When designing lesson plans for teaching a skill, teachers commonly build in class time and homework for students to practice the skill initially (referred to as *massed practice*). It is not as common for teachers to plan for distributed practice, which occurs over a longer period of time and helps students achieve automaticity with the skill. Establishing a schedule on a planning calendar and sharing this schedule with students emphasizes the importance of distributed practice. Further, when students learn a skill near the end of the year, the teacher might recommend to students a specific summer schedule for distributed practice and explain the role of practice in achieving automaticity. Some students will not follow the schedule; however, the idea of distributed practice might help them better understand the process of learning a skill, as exemplified by Illustration 2.

ILLUSTRATION 1: DISCOVERY APPROACH TO SKILLS *driver's education*

Students in Mr. Prado's driver's education class were skilled enough in their driving that he thought that they were ready to learn to drive on different surfaces. To capture their attention and interest, Mr. Prado decided to have students discover some rules for the road, so to speak.

With the help of the administration, he set up a concourse with several different driving surfaces — dry pavement, wet pavement, oil-slicked pavement, snow-covered pavement, gravel, and a rutted dirt surface. He had students drive on all six surfaces. Then he asked students to form small groups and discuss what driving on all surfaces had in common, what was different, and, finally, articulate a strategy for driving safely and effectively on each surface.

ILLUSTRATION 2: DISTRIBUTED PRACTICE *letters of the alphabet*

Ms. Fontana's first grade students were excited about learning to write the alphabet. Once students learned to print a set of related letters, Ms. Fontana set up a practice schedule for that set.

At first, students printed the letters over and over for an entire lesson. They also practiced the letters for homework. The next day they again practiced a lot, but not for the entire lesson. Over the next two days, Ms. Fontana decreased the number of times students printed each letter. Then she had students practice every other day, then every third day, and so on. However, students never completely stopped practicing the alphabet.

Ms. Fontana planned for distributed practice throughout the year. At least once every two weeks, students practiced printing the alphabet, either in class or for homework. In this way, students learned to print the letters automatically, accurately, and quickly.

PROCESSES

1. Give Students a General Model of the Overall Components and Subcomponents of New Processes.
(See Illustration 1)

Students need a fair amount of guidance when first learning a complex process. One of the best ways to provide this guidance is to give them a model of the overall components and subcomponents of the process, as exemplified by Illustration 1.

2. Have Students Focus on a Specific Subcomponent in the Context of a Process.
(See Illustration 2)

In general, students should not practice the subcomponents of a complex process in isolation. It's much more useful to practice them in the context of the entire process. To facilitate this type of practice, tasks should be structured to emphasize a specific subcomponent, as shown in Illustration 2. The following activities can help students focus on specific subcomponents of a process:

- Help students clearly identify the specific subcomponent (e.g., skill, strategy) they are going to practice and set criteria for evaluating their own progress.

- Give students a variety of assignments over time that require them to use the targeted skill or strategy within the context of the process.

- Encourage students to self-assess, but also give them feedback on the targeted skill or strategy. To help students focus, avoid giving feedback on other aspects of the process.

ILLUSTRATION 1: GIVE STUDENTS A GENERAL MODEL *the research process*

At the beginning of each school year, teachers at Andrew Lewis Middle School presented students in each grade with the following model for the research process:

Define your topic.
- State your topic as a question.
- Identify keywords to help you search for information.
- Develop your thesis statement.

Locate resources.
- Determine what kind of information you need to look for.
- Use your keywords to search for books, articles, and other resources.

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ILLUSTRATION 1 *(continued)*

Evaluate the information you find.
- Determine if the information presented is fact or opinion.
- Determine if the information is well-supported by evidence.
- Determine if the information presented has a particular bias or is misleading.
- Determine if there are any errors in reasoning in the information.

Organize your information.
- Synthesize information.
- Prepare quotations from sources to use.
- Determine the best way to present your information.

Cite your information.
- Check all references within the text.
- Cite your sources completely and accurately.
- Create a list of works cited.

The components of the research process were new to sixth grade students, but became more familiar as each year passed. At every grade level, students learned and reviewed the overall process and its major components and focused on specific subcomponents designated for their grade level.

In one sixth grade classroom, as David worked on organizing his information, Ms. Waniki suggested that he review his topic question and then refine his thesis if he thought it was necessary. When Shana evaluated the information she had gathered, Ms. Waniki suggested that it might be a good time to make sure she had all the necessary information for her list of works cited. Teachers at Andrew Lewis Middle School used the research process consistently so that by the time students left sixth grade, they were very familiar with the interrelated components of research and used the individual components easily.

ILLUSTRATION 2: FOCUS ON A SPECIFIC SUBCOMPONENT *the research process*

At Andrew Lewis Middle School, teachers at each grade level took responsibility for teaching specific subcomponents of the research process. For example, the sixth grade teachers worked with students on five subcomponents throughout the year — state your topic as a question, identify keywords to help you search for information, use your keywords to search for books, articles, and other resources; determine if the information presented is fact or opinion, and prepare quotations from sources to use. The sixth graders practiced these subcomponents in various assignments all year long, so that when they reached the seventh grade, they could use these subcomponents.

THEORY AND RESEARCH IN BRIEF • • •
Teaching specific types of knowledge

VOCABULARY TERMS AND PHRASES — One of the most generalizable findings in the research about vocabulary development is the strong relationship between vocabulary and a number of important factors, such as intelligence (Thorndike & Lorge, 1943; Davis, 1944; Spearitt, 1972), one's ability to comprehend new information (Chall, 1958; Harrison, 1980), and one's level of income (Sticht, Hofstetter, & Hofstetter, 1997). Expending time and resources on vocabulary instruction, therefore, seems justified, given the importance of vocabulary development.

In a major review of the research on vocabulary, researchers Stahl and Fairbanks (1986) found that teaching general vocabulary directly had an overall effect size of .32. Although this is not a huge effect size, it has practical significance. It means that teaching vocabulary directly increases student comprehension of new material by 12 percentile points.

To illustrate, assume that two students of equal ability are asked to read and understand new information. However, student A is in a program where about 10 to 12 new vocabulary words are taught each week. According to Nagy and Herman (1984), this is the typical number of words provided to students in vocabulary programs. Student B does not receive this instruction. Now assume that students A and B take a test on the new content and that student B receives a score that places him at the 50th percentile relative to other students in the class. All else being equal, student A will receive a score that places her at the 62nd percentile on that same test simply because she received systematic vocabulary instruction. A 12 percentile-point increase in achievement is not insignificant in a practical sense.

The effects of vocabulary instruction are even more powerful when the words selected are those that students most likely will encounter when they learn new content. Specifically, research by Stahl and Fairbanks (1986) indicates that student achievement will increase by 33 percentile points when vocabulary instruction focuses on specific words that are important to what students are learning. To illustrate, again consider students A and B who have been asked to read and understand new content. Student B, who has not received systematic vocabulary instruction, receives a score on the test that puts her at the 50th percentile. Student A, who has received systematic instruction on words *that have been specifically selected because they are important to the new content,* will obtain a score that puts him at 83rd percentile.

DETAILS — As the name implies, details are very specific pieces of information. This category of knowledge includes facts, time sequences, cause/effect sequences, and episodes.

Facts

Facts are a very specific type of informational content. Facts convey information about specific persons, places, living and nonliving things, and events. They commonly articulate information such as the following:

- The characteristics of a specific person (e.g., Ronald Reagan served as president of the United States from 1981–1989).
- The characteristics of a specific place (e.g., Richmond is the capital of Virginia).
- The characteristics of specific living and nonliving things (e.g., my cat, Fluffy, weighs more than 20 pounds; the Golden Gate Bridge stretches 4,200 feet and the suspended towers are 746 feet above the water).
- The characteristics of a specific event (e.g., the Soviet Union's Sputnik I, the first manmade satellite, launched on October 4, 1957).

Time Sequences

Time sequences include important events that occurred between two points in time. For example, the events that occurred between Iraq's invasion of Kuwait on August 2, 1990, and the United States' air attacks on Baghdad, Iraq, on January 16, 1991, can be organized as a time sequence. First one thing happened, then another, then another.

Cause/Effect Sequences

Cause/effect sequences involve events that produce a product or an effect. A causal sequence can be as simple as a single cause for a single effect. For example, the fact that the game was won because a certain player passed the ball to another player, who kicked in the winning goal, can be organized as a causal sequence. More commonly, however, effects have complex networks of causes; one event affects another, which combines with a third event to affect a fourth, which then affects another, and so on. For example, the events leading up to the French Revolution can be organized as a casual sequence.

Episodes

Episodes are specific events that have (1) a setting (i.e., a particular time and place); (2) specific participants; (3) a particular duration; (4) a specific sequence of events; and (5) a particular cause and effect. For example, the events of Shay's Rebellion (1786–1787) can be organized as an episode. The rebellion occurred at a particular time and place; it had specific participants; it lasted for a specific duration of time; it involved a specific sequence of events; it was caused by specific events; and it had a specific effect on the country.

Perhaps the most striking findings from the research on details is that students must encounter details frequently if they are to learn them at a deep enough level to understand and recall them.

Specifically, research by Nuthall (1999; Nuthall & Alton-Lee, 1995) indicates that students should be exposed to details at least three or four times before they can legitimately be expected to remember those details or use them in any meaningful way.

In addition, it has been found that, in general, the time between exposures to details should not exceed about two days. The need for multiple exposures to details and for those exposures to be relatively close in time has been called the "time window" for learning (Rovee-Collier, 1995). To illustrate, assume that the topic of the Battle of Gettysburg has been introduced to students in a section of a textbook. The teacher and the students read the section aloud and discuss it. Within two days, this same topic must be revisited in some way. The teacher can simply engage students in a discussion of the content, or he might present more information in the form of a brief presentation by having students read another section in the textbook, by showing a film, and so on. Within another two days, the information must be revisited again, and again within another two days, and then again within two days after that.

Another interesting finding on teaching details is that different types of instruction produce different effects on student learning. Specifically, students' understanding and recollection of details is different depending on whether instruction is verbal, visual, or dramatic. These differences can be seen in Table 11.1.

As its name implies, *verbal instruction* involves telling students about details or having them read about details. Although verbal instruction has fairly impressive effects on students' understanding and recall of details immediately after instruction and a year later, it has the weakest effect of the three.

Table 11.1: Types of Instruction and Effect on Learning

Type of Instruction	Effect Size Immediately After Instruction	Effect Size After 12 Months
Verbal instruction	.74	.64
Visual instruction	.90	.74
Dramatic instruction	1.12	.80

Note: Data computed from "The Way Students Learn: Acquiring Knowledge from an Integrated Science and Social Studies Unit," by G. Nuthall, 1999, *Elementary School Journal, 99*(4), 303–341; and from "Assessing Classroom Learning: How Students Use Their Knowledge and Experience to Answer Classroom Achievement Test Questions in Science and Social Studies," by G. Nuthall, & A. Alton-Lee, 1995, *American Educational Research Journal, 32*(1), 185–223.

Visual instruction emphasizes some form of nonlinguistic representation. We saw in Chapter 6 that this might involve graphic representations, pictures and pictographs, creating mental pictures or concrete representations, or engaging in some kind of kinesthetic activity. The effects on learning for visual instruction are better than verbal instruction both immediately after instruction and one year later. However, its effects are not as strong as the effect for the third category of instruction: dramatization.

When instruction emphasizes *dramatization*, students either observe a dramatic enactment of the details or are involved in a dramatic enactment of the details. As Table 11.1 illustrates, in studies by Nuthal and his colleagues this type of instruction had the strongest effects both immediately after instruction and one year later.

ORGANIZING IDEAS — Organizing ideas, such as generalizations and principles, are the most general type of informational knowledge.[2] Generalizations are statements for which examples can be provided because they apply to many different situations. For example, the statement, "U.S. presidents often come from families that have great wealth or influence" is a generalization for which examples can be provided. Principles are specific types of generalizations that articulate rules or relationships that can be applied to a number of specific situations. For instance, "water seeks its own level" is a scientific principle.

Generalizations

Although vocabulary terms and details are important, generalizations help students develop a broad knowledge base because they transfer more readily to different situations. For instance, consider the generalization, "Specific battles sometimes disproportionately influence the outcome of a war." This generalization can be applied across countries, situations, and time periods, whereas a fact about the Battle of Gettysburg is a specific event that does not directly transfer to other situations. This is not to say that details are unimportant. On the contrary, to truly understand generalizations students must be able to support them with exemplifying facts. For instance, to understand the generalization about the influences of specific battles, students need a rich set of illustrative facts, which may include facts about the Battle of Gettysburg.

It is easy to confuse some generalizations with some facts. Facts identify characteristics of specific persons, places, living and nonliving things, and events, whereas generalizations identify characteristics about *classes or categories* of persons, places, living and nonliving things, and events. For example, the statement, "My Portuguese Water Dog, Sparky, is a good swimmer," is a fact. However, the statement, "Portuguese Water Dogs are good swimmers" is a generalization.

Generalizations also articulate characteristics about abstractions. Specifically, information about abstractions is always stated in the form of generalizations. Below are examples of the various types of generalizations:

- Characteristics of classes of persons (e.g., It takes at least eight years of training to become a doctor.)
- Characteristics of classes of places (e.g., Humid climates have a lot of mosquitos.)
- Characteristics of classes of living and nonliving things (e.g., The states in the western United States have a high population of immigrants from Mexico.)

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[2]*Note:* We have not included *concepts* as organizing ideas because, technically defined, they are synonymous with generalizations (see Gagne, 1977).

- Characteristics of classes of events (e.g., Fourth of July celebrations have the best fireworks displays.)
- Characteristics of abstractions (e.g., Love is one of the most powerful human emotions.)

Principles

In general, there are two types of principles found in school-related declarative knowledge: *cause/effect principles* and *correlational principles*.

Cause/effect principles — Cause/effect principles articulate causal relationships. For example, the statement, "germs cause many diseases" is a cause/effect principle. Understanding a cause/effect principle involves understanding the specific elements in the cause/effect system and the exact relationships those elements have to one another. To understand the cause/effect principle regarding germs and diseases, students would have to understand the sequence of events that occur, the elements involved, and the type and strength of relationships between those elements. In short, understanding a cause/effect principle involves understanding a great deal of information.

Correlational principles **—** Correlational principles describe relationships that are not necessarily causal in nature, but in which a change in one factor is associated with a change in another factor. For example, the following is a correlational principle: "The decrease in prostate cancer deaths among men is directly proportional to the increase in the number of men who take screening tests."

Again, to understand this principle, a student would have to know the specific details about this relationship. Specifically, a student would have to know the general pattern of this relationship, that is, that the number of men who die from prostate cancer decreases as the number of men who get tested increases.

These two types of principles are sometimes confused with cause/effect sequences. A cause/effect sequence applies to a specific situation, whereas a principle applies to many situations. The causes of the French Revolution taken together represent a cause/effect sequence. They apply to the French Revolution only. However, the cause/effect principle linking germs and diseases can be applied to many different diseases and many different people. Physicians use this principle to make judgments about a variety of situations and a variety of people. The key distinction between principles and cause/effect sequences is that principles can be exemplified in a number of situations, whereas cause/effect sequences cannot — they apply to a single situation only.

The research on teaching generalizations and principles is fairly extensive. One of the more extensive reviews was done by Ross in 1988. Of the many findings in that review, one of the most useful to the classroom teacher is that students should be provided with more opportunities to apply generalizations and principles once they understand them. This seems counterintuitive to some educators who put the majority of their energies into helping students initially understand generalizations and principles. In fact, some teachers insist on having students discover generalizations and principles as opposed to presenting them in a rather direct fashion at first, but then structure activities so that students can apply their new knowledge.

Nonetheless, structured discovery lessons are very powerful learning experiences for generalizations and principles. However, they are very time consuming to implement and very difficult to design. In many situations, students might be better served if teachers presented generalizations and principles in a somewhat direct manner but then gave students plenty of opportunities to apply the generalizations and principles to new situations.

SKILLS — There are two forms of mental skills: *tactics* and *algorithms* (see Snowman & McCown, 1984). *Tactics* are general rules governing an overall flow of execution, rather than a set of steps that must be performed in a specific order. For example, a tactic for reading a histogram might address (1) identifying the elements defined in the legend, (2) determining what is reported on each axis of the graph, and (3) determining the relationship between the elements on the two axes. Although there is a general pattern in which these rules are carried out, there is no rigid or set order. *Algorithms* are mental skills that have very specific outcomes and very specific steps. Performing multi-column subtraction is an illustration of an algorithm. Although the steps in a tactic do not have to be performed in a set order, the steps in an algorithm do. Obviously, changing the order in which the steps of multi-column subtraction are performed will dramatically change the answer that is computed.

A common misconception in education is that “discovering” how to perform a skill or tactic is always better than being directly taught the skill or process. This misconception probably gained favor in reaction to the long-held misconception that drill and practice in specific steps is always the best way to teach skills and tactics (for a discussion, see Anderson, Reder, & Simon, 1997). The truth about instruction on skills and tactics lies somewhere in the middle. Some skills are best learned through discovery. Some are best learned through direct instruction. For example, consider the skills of addition, subtraction, multiplication, and division. To have students discover the steps involved in addition, subtraction, multiplication, and division makes little sense. Although it is probably true that students would certainly understand these skills well if they were required to discover the steps to addition, it is also true that this would take an inordinate amount of time. However, it might make good sense to have students discover strategies for solving specific types of addition problems.

Although there is no magic list of the algorithms and tactics that are best suited for a discovery approach, a useful rule of thumb is that the more variation there is in the steps that can be used to effectively execute a skill or a tactic (e.g., in the order of the steps, the number of steps, and even the steps themselves), the more amenable the skill or tactic is to discovery learning. For example, if five steps must be followed in a specific order to properly use a piece of equipment in a science lab, then it is questionable whether the best approach is for students to discover these five steps and their order of execution. It might be better to demonstrate those steps and then provide opportunities for students to alter them to suit their individual needs and styles. On the other hand, a tactic that can be executed in a number of ways is probably a good candidate for discovery learning.

One of the best examples of using a discovery approach with skill-based knowledge is Cognitively Guided Instruction (see Carpenter, Fennema, & Franke, undated; Carpenter, Fennema, & Peterson, 1987; Carpenter et al., 1989; Fennema, Carpenter, & Franke, 1992; Fennema, Carpenter, & Peterson, 1989; Peterson, Carpenter, & Fennema, 1989; Peterson, Fennema, & Carpenter, 1989). Using this approach, primary students are encouraged to "design" their own strategies for solving problems. As described by Fennema, Carpenter, and Franke (1992):

> Children are not shown how to solve the problems. Instead each child solves them in any way that s/he can, sometimes in more than one way, and reports how the problem was solved to peers and teacher. The teacher and peers listen and question until they understand the problem solutions, and then the entire process is repeated. Using information from each child's reporting of problem solutions, teachers make decisions about what each child knows and how instruction should be structured to enable that child to learn. (p. 5)

Key to the success of this highly discovery-oriented approach is teachers' awareness of the types of problems that are the basis for a more complex understanding of computational facts and problem-solving strategies. These problem types are shown in Table 11.2.

Table 11.2: Types of Word Problems

Join	(*Result Unknown)* Connie had 5 marbles. Juan gave her 8 more marbles. How many marbles does Connie have altogether?	*(Change Unknown)* Connie has 5 marbles. How many more marbles does she need to have 13 marbles altogether?	(*Start Unknown)* Connie had some marbles. Juan gave her 5 more marbles. Now she has 13 marbles. How many marbles did Connie have to start with?
Separate	(*Result Unknown)* Connie had 13 marbles. She gave 5 to Juan. How many marbles does Connie have left?	*(Change Unknown)* Connie had 13 marbles. She gave some to Juan. Now she has 5 marbles left. How many marbles did Connie give to Juan?	(*Start Unknown)* Connie had some marbles. She gave 5 to Juan. Now she has 8 marbles left. How many marbles did Connie have to start with?
Part-Part-Whole	(*Whole Unknown*) Connie has 5 red marbles and 8 blue marbles? How many marbles does she have?	(*Part Unknown*) Connie has 13 marbles. 5 are red and the rest are blue. How many blue marbles does Connie have?	
Compare	(*Difference Unknown*) Connie has 13 marbles. Juan has 5 marbles. How many more marbles does Connie have than Juan?	(*Compare Quantity Unknown)* Juan has 5 marbles. Connie has 8 more than Juan. How many marbles does Connie have?	(*Referent Unknown*) Connie has 13 marbles. She has 5 more marbles than Juan. How many marbles does Juan have?

Note: Reprinted (adapted) from *Children's Mathematics: Cognitively Guided Instruction*, by T. P. Carpenter, E. Fennema, M. L. Franke, L. Levi, and S. B. Empson, 1999, Portsmouth, NH: Heinemann.

With a knowledge of these problem types, a teacher can effectively guide student inquiry. The teacher would provide students with more practice in the specific problem type when needed and introduce the next problem type when appropriate. As students practiced a specific type of problem, they would devise and test out strategies for that type. In short, for inquiry to be effective, examples of the skill or tactic that is the target of the discovery approach should be in well-organized categories that represent different ways of executing the skill or tactic. As students work through the different categories, they are developing different ways of performing the skill or tactic.

PROCESSES — Processes are similar to skills and tactics in some ways and different in other ways. They are similar in that they produce some form of result or product. For example, the tactic of reading a bar graph leads to a new understanding of the relationship between two variables. The process of writing produces a new composition. However, processes have a much higher tolerance for variation relative to the steps involved than do tactics or skills. For example, there are not many ways to go about reading a bar graph. However, there are many different ways to engage in the process of writing. We might say that processes are more "robust" than skills and tactics in terms of how they can be performed.

By definition, processes are not amenable to a "step-by-step" instructional approach. But this does not mean that teachers should not give students guidance in the general aspects of the process. For example, it is common to provide a description of the various components involved in writing. Occasionally, such an approach is referred to as the "process writing approach." To illustrate, the following phrases (or adaptations of them) are commonly presented to students as components of the writing process:

- Prewriting
- Writing
- Revising

Within each of these major components of the writing process, more specific subcomponents are identified. For example, within the revising component of the writing process, the following subcomponents might be presented to students:

- Revising:
  - Revising for the overall logic of the composition
  - Revising for effective transitions
  - Revising for word choice and phrasing
  - Revising for subject-verb agreement
  - Revising for spelling and punctuation

Obviously, students must be presented with the components and subcomponents of a process and practice those components and subcomponents. The research on writing offers an insight into how this is best accomplished. Specifically, Hillocks (1986) examined four approaches to teaching writing, which can be described as follows:

- *Presentation:* The teacher explains what good writing is and gives examples.
- *Natural process:* The teacher has students engage in a great deal of free writing, individually and in groups.
- *Focused practice:* The teacher engages students in the entire process of writing but focuses on specific aspects of writing. Skills are not taught in isolation.
- *Skills:* The teacher breaks writing down into its component parts and then gives students opportunities to practice each part, commonly in isolation.

The effect sizes for each of these approaches is reported in Table 11.3. As Table 11.3 shows, the approach that most powerfully influences students' writing ability is focused practice.

Table 11.3: Effect Sizes for Various Approaches to Writing

Approach	**No. of Effect Sizes**	**Ave. Effect Size**	**Percentile Gain[a]**
Presentation	4	.02	1
Natural process	9	.19	8
Focused practice	10	.44	17
Skills	6	.17	6

Source: Research on Written Composition, by G. Hillocks, 1986, Urbana, IL: ERIC Clearinghouse on Reading and Communication Skills and National Conference on Research in English.
[a]These are the maximum percentile gains possible for students currently at the 50th percentile.

To use the focused practice approach, a teacher presents students with the components and subcomponents of the process and then structures tasks that emphasize a specific component or subcomponent. For example, a teacher might assign a composition that emphasizes the subcomponent of revising for overall logic or revising for transitions. It is interesting to note that simply explaining to students what good writing is (i.e., the "presentation" approach) resulted in the lowest effect size in the studies reviewed. It is also interesting to note how small the effect sizes were for simply asking students to write a great deal (i.e., the "natural process" approach) and to practice the components and subcomponents in isolation (i.e., the "skills" approach).