A Taxonomy for Learning, Teaching, and Assessing

A Revision of Bloom's Taxonomy of Educational Objectives

COMPLETE EDITION

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CHAPTER 5

The Cognitive Process Dimension

In Chapter 4 we described each of the four types of knowledge in detail. Although much of schooling focuses on *Factual knowledge*, we suggested that this limited focus can be expanded by placing greater emphasis on a broader range of knowledge types, including *Conceptual knowledge*, *Procedural knowledge*, and *Metacognitive knowledge*. Similarly, in this chapter we suggest that although instruction and assessment commonly emphasize one kind of cognitive processing—*Remembering*—schooling can be expanded to include a broader range of cognitive processes. In fact, the predominant use of the original framework has been in the analysis of curricula and examinations to demonstrate their overemphasis on remembering and their lack of emphasis on the more complex process categories (Anderson and Sosniak, 1994). The purpose of this chapter is to describe the full range of processes in more detail.

Two of the most important educational goals are to promote retention and to promote transfer (which, when it occurs, indicates meaningful learning). Retention is the ability to remember material at some later time in much the same way as it was presented during instruction. Transfer is the ability to use what was learned to solve new problems, to answer new questions, or to facilitate learning new subject matter (Mayer and Wittrock, 1996). In short, retention requires that students **remember** what they have learned, whereas transfer requires students not only to remember but also to **make sense of** and **be able to use** what they have learned (Bransford, Brown, and Cocking, 1999; Detterman and Sternberg, 1993; McKeough, Lupart, and Marini, 1995; Mayer, 1995; Phye, 1997). Stated somewhat differently, retention focuses on the **past**, whereas transfer emphasizes the **future**. After students read a textbook lesson on Ohm's law, for example, a retention test might ask them to write the formula for Ohm's law. In contrast, a transfer test might ask students to rearrange an electrical circuit to maximize the rate of electron flow or to use Ohm's law to explain a complex electric circuit.

Although educational objectives for promoting retention are fairly easy to construct, educators may have more difficulty in formulating, teaching, and assessing objectives aimed at promoting transfer (Baxter, Elder, and Glaser, 1996; Phye, 1997). Our revised framework is intended to help broaden the typical set of educational objectives to include those aimed at promoting transfer. We begin this chapter by introducing retention and transfer. Next, we describe our six cognitive process categories (one that emphasizes retention and five that, although they may facilitate retention, emphasize transfer). We end the chapter with an example of how this discussion can be applied to teaching, learning, and assessing a lesson on Ohm's law.

A Tale of Three Learning Outcomes

As an introduction, we briefly consider three learning scenarios. The first exemplifies no learning (that is, no intended learning), the second rote learning, and the third meaningful learning.

No Learning

Amy reads a chapter on electrical circuits in her science textbook. She skims the material, sure that the test will be a breeze. When she is asked to recall part of the lesson (as a retention test), she is able to remember very few of the key terms and facts. For example, she cannot list the major components in an electrical circuit even though they were described in the chapter. When she is asked to use the information to solve problems (as part of a transfer test), she cannot. For example, she cannot answer an essay question that asks her to diagnose a problem in an electrical circuit. In this worst-case scenario, Amy neither possesses nor is able to use the relevant knowledge. Amy has neither sufficiently attended to nor encoded the material during learning. The resulting outcome can be characterized as essentially **no learning**.

Rote Learning

Becky reads the same chapter on electrical circuits. She reads carefully, making sure she reads every word. She goes over the material and memorizes the key facts. When she is asked to recall the material, she can remember almost all of the important terms and facts in the lesson. Unlike Amy, she is able to list the major components in an electrical circuit. When she is asked to use the information to solve problems, however, she cannot. Like Amy, she cannot answer the essay question about the diagnosis of a problem in an electrical circuit. In this scenario, Becky possesses relevant knowledge but cannot use that knowledge to solve problems. She cannot transfer this knowledge to a new situation. Becky has attended to relevant information, but she has not understood it and therefore cannot use it. The resulting learning outcome can be called **rote learning**.

Meaningful Learning

Carla reads the same textbook chapter on electrical circuits. She reads carefully, trying to make sense out of it. When she is asked to recall the material, she, like Becky, can remember almost all of the important terms and facts in the lesson. Furthermore, when she is asked to use the information to solve problems, she generates many possible solutions. In this scenario, not only does Carla possess relevant knowledge, but she also can use that knowledge to solve problems and to understand new concepts. She can transfer her knowledge to new problems and new learning situations. Carla has attended to relevant information and has understood it. The resulting learning outcome can be called **meaningful learning**.

Meaningful learning provides students with the knowledge and cognitive processes they need for successful problem solving. Problem solving occurs when a student devises a way of achieving a goal that he or she has never previously achieved, that is, of figuring out how to change a situation from its given state into a goal state (Duncker, 1945; Mayer, 1992). Two major components in problem solving are problem representation—in which a student builds a mental representation of the problem—and problem solution—in which a student devises and carries out a plan for solving the problem (Mayer, 1992). Consistent with recent research (Gick and Holyoak, 1980, 1983; Vosniadou and Ortony, 1989), the authors of the original *Handbook* recognized that students often solve problems by analogy. That is, they reformulate the problem in a more familiar form, recognize that it is similar to a familiar problem type, abstract the solution method for that familiar problem type, and then apply the method to the to-be-solved problem.

Meaningful Learning as Constructing Knowledge Frameworks

A focus on meaningful learning is consistent with the view of learning as knowledge construction, in which students seek to make sense of their experiences. In constructivist learning, as mentioned on page 38, students engage in active cognitive processing, such as paying attention to relevant incoming information, mentally organizing incoming information into a coherent representation, and mentally integrating incoming information with existing knowledge (Mayer, 1999). In contrast, a focus on rote learning is consistent with the view of learning as knowledge acquisition, in which students seek to add new information to their memories (Mayer, 1999).

Constructivist learning (i.e., meaningful learning) is recognized as an important educational goal. It requires that instruction go beyond the simple presentation of factual knowledge and that assessment tasks require more of students than simply recall or recognition of factual knowledge (Bransford, Brown, and Cocking, 1999; Lambert and McCombs, 1998; Marshall, 1996; Steffe and Gale, 1995). The cognitive processes summarized in this chapter provide a means of describing the range of students' cognitive activities in constructivist learning; that is, these processes are ways in which students can actively engage in the process of constructing meaning.

Cognitive Processes for Retention and Transfer

If we were interested mainly in teaching and assessing the degree to which students learned some subject matter content and retained it over some period of time, we would focus primarily on one class of cognitive processes—namely, those associated with *Remember*. In contrast, if we wish to expand our focus by examining ways to foster and assess meaningful learning, we need to examine processes that go beyond remembering.

What cognitive processes are used for retention and transfer? As we discussed, our revised framework includes six categories of processes—one most closely related to retention (*Remember*) and the other five increasingly related to transfer (*Understand, Apply, Analyze, Evaluate,* and *Create*). Based on a review of the illustrative objectives listed in the original *Handbook* and an examination of other classification systems (e.g., DeLandsheere, 1977; Metfessel, Michael, and Kirsner, 1969; Mosenthal, 1998; Royer, Ciscero, and Carlo, 1993; Sternberg, 1998), we have selected 19 cognitive processes that fit within these six categories. Table 5.1 provides a brief definition and example of each cognitive process, lists their alternative names, and indicates the category to which it belongs. These 19 specific cognitive processes are intended to be mutually exclusive; together they delineate the breadth and boundaries of the six categories.

CATEGORIES OF THE COGNITIVE PROCESS DIMENSION

In the discussion that follows, we define the cognitive processes within each of the six categories in detail, making comparisons with other cognitive processes, where appropriate. We offer sample educational objectives and assessments in various subject areas as well as alternative versions of assessment tasks. Each illustrative objective in the following material should be read as though preceded by the phrase "The student is able to . . ." or "The student learns to. . . ."

1. REMEMBER

When the objective of instruction is to promote retention of the presented material in much the same form as it was taught, the relevant process category is *Remember.* Remembering involves retrieving relevant knowledge from long-term memory. The two associated cognitive processes are *recognizing* and *recalling*. The relevant knowledge may be *Factual, Conceptual, Procedural,* or *Metacognitive,* or some combination of these.

To assess student learning in the simplest process category, the student is given a recognition or recall task under conditions very similar to those in which he or she learned the material. Little, if any, extension beyond those conditions is expected. If, for example, a student learned the English equivalents of 20 Spanish words, then a test of remembering could involve requesting the student to match the Spanish words in one list with their English equivalents in a second list (i.e., *recognize*) or to write the corresponding English word next to each of the Spanish words presented in the list (i.e., *recall*).

Remembering knowledge is essential for meaningful learning and problem solving as that knowledge is used in more complex tasks. For example, knowledge of the correct spelling of common English words appropriate to a given grade level is necessary if the student is to master writing an essay. Where teachers concentrate solely on rote learning, teaching and assessing focus solely on remembering elements or fragments of knowledge, often in isolation from their context. When teachers focus on meaningful learning, however, re-

5.1 THE COGNITIVE PROCESS DIMENSION

CATEGORIES & COGNITIVE PROCESSES	ALTERNATIVE NAMES	DEFINITIONS AND EXAMPLES
1. REMEMBER—Retrieve relevant knowledge from long-term memory		
1.1 RECOGNIZING	Identifying	Locating knowledge in long-term memory that is consistent with presented material (e.g., Recognize the dates of important events in U.S. history)
1.2 RECALLING	Retrieving	Retrieving relevant knowledge from long-term memory (e.g., Recall the dates of important events in U.S. history)
2. UNDERSTAND—Construct meaning from instructional messages, including oral, written, and graphic communication		
2.1 INTERPRETING	Clarifying, paraphrasing, representing, translating	Changing from one form of representation (e.g., numerical) to another (e.g., verbal) (e.g., Paraphrase important speeches and documents)
2.2 EXEMPLIFYING	Illustrating, instantiating	Finding a specific example or illustration of a concept or principle (e.g., Give examples of various artistic painting styles)
2.3 CLASSIFYING	Categorizing, subsuming	Determining that something belongs to a category (e.g., concept or principle) (e.g., Classify observed or described cases of mental disorders)
2.4 SUMMARIZING	Abstracting, generalizing	Abstracting a general theme or major point(s) (e.g., Write a short summary of the events portrayed on a videotape)
2.5 INFERRING	Concluding, extrapolating, interpolating, predicting	Drawing a logical conclusion from presented information (e.g., In learning a foreign language, infer grammatical principles from examples)
2.6 COMPARING	Contrasting, mapping, matching	Detecting correspondences between two ideas, objects, and the like (e.g., Compare historical events to contemporary situations)
2.7 EXPLAINING	Constructing models	Constructing a cause-and-effect model of a system (e.g., Explain the causes of important 18th-century events in France)
3. APPLY—Carry out or use a procedure in a given situation		
3.1 EXECUTING	Carrying out	Applying a procedure to a familiar task (e.g., Divide one whole number by another whole number, both with multiple digits)
3.2 IMPLEMENTING	Using	Applying a procedure to an unfamiliar task (e.g., Use Newton's Second Law in situations in which it is appropriate)

5.1 The Cognitive Process Dimension (continued)

Categories & Cognitive Processes	Alternative Names	Definitions and Examples
4. ANALYZE—Break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose		
4.1 Differentiating	Discriminating, distinguishing, focusing, selecting	Distinguishing relevant from irrelevant parts or important from unimportant parts of presented material (e.g., Distinguish between relevant and irrelevant numbers in a mathematical word problem)
4.2 Organizing	Finding coherence, intergrating, outlining, parsing, structuring	Determining how elements fit or function within a structure (e.g., Structure evidence in a historical description into evidence for and against a particular historical explanation)
4.3 Attributing	Deconstructing	Determine a point of view, bias, values, or intent underlying presented material (e.g., Determine the point of view of the author of an essay in terms of his or her political perspective)
5. EVALUATE—Make judgments based on criteria and standards		
5.1 Checking	Coordinating, detecting, monitoring, testing	Detecting inconsistencies or fallacies within a process or product; determining whether a process or product has internal consistency; detecting the effectiveness of a procedure as it is being implemented (e.g., Determine if a scientist's conclusions follow from observed data)
5.2 Critiquing	Judging	Detecting inconsistencies between a product and external criteria, determining whether a product has external consistency; detecting the appropriateness of a procedure for a given problem (e.g., Judge which of two methods is the best way to solve a given problem)
6. CREATE—Put elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure		
6.1 Generating	Hypothesizing	Coming up with alternative hypotheses based on criteria (e.g., Generate hypotheses to account for an observed phenomenon)
6.2 Planning	Designing	Devising a procedure for accomplishing some task (e.g., Plan a research paper on a given historical topic)
6.3 Producing	Constructing	Inventing a product (e.g., Build habitats for a specific purpose)

membering knowledge is integrated within the larger task of constructing new knowledge or solving new problems.

1.1 Recognizing

Recognizing involves retrieving relevant knowledge from long-term memory in order to compare it with presented information. In *recognizing,* the student searches long-term memory for a piece of information that is identical or extremely similar to the presented information (as represented in working memory). When presented with new information, the student determines whether that information corresponds to previously learned knowledge, searching for a match. An alternative term for *recognizing* is identifying.

Sample Objectives and Corresponding Assessments In social studies, an objective could be for students to recognize the correct dates of important events in U.S. history. A corresponding test item is: "True or false: The Declaration of Independence was adopted on July 4, 1776." In literature, an objective could be to recognize authors of British literary works. A corresponding assessment is a matching test that contains a list of ten authors (including Charles Dickens) and a list of slightly more than ten novels (including *David Copperfield*). In mathematics, an objective could be to recognize the numbers of sides in basic geometric shapes. A corresponding assessment is a multiple-choice test with items such as the following: "How many sides does a pentagon have? (a) four, (b) five, (c) six, (d) seven."

Assessment Formats As illustrated in the preceding paragraph, three main methods of presenting a recognition task for the purpose of assessment are verification, matching, and forced choice. In verification tasks, the student is given some information and must choose whether or not it is correct. The true-false format is the most common example. In matching, two lists are presented, and the student must choose how each item in one list corresponds to an item in the other list. In forced choice tasks, the student is given a prompt along with several possible answers and must choose which answer is the correct or "best answer." Multiple-choice is the most common format.

1.2 Recalling

Recalling involves retrieving relevant knowledge from long-term memory when given a prompt to do so. The prompt is often a question. In *recalling,* a student searches long-term memory for a piece of information and brings that piece of information to working memory where it can be processed. An alternative term for *recalling* is retrieving.

Sample Objectives and Corresponding Assessments In *recalling,* a student remembers previously learned information when given a prompt. In social studies, an objective could be to recall the major exports of various South American countries. A corresponding test item is "What is the major export of Bolivia?" In literature, an objective could be to recall the poets who wrote various poems. A corresponding test question is "Who wrote *The Charge of the Light Brigade*?" In mathematics, an objective could be to recall the whole-number multiplication facts. A corresponding test item asks students to multiply 7×8 (or "$7 \times 8 = ?$").

ASSESSMENT FORMATS Assessment tasks for *recalling* can vary in the number and quality of cues that students are provided. With low cueing, the student is not given any hints or related information (such as "What is a meter?"). With high cueing, the student is given several hints (such as "In the metric system, a meter is a measure of ________.").

Assessment tasks for *recalling* can also vary in the amount of embedding, or the extent to which the items are placed within a larger meaningful context. With low embedding, the recall task is presented as a single, isolated event, as in the preceding examples. With high embedding, the recall task is included within the context of a larger problem, such as asking a student to recall the formula for the area of a circle when solving a word problem that requires that formula.

2. UNDERSTAND

As we indicated, when the primary goal of instruction is to promote retention, the focus is on objectives that emphasize *Remember*. When the goal of instruction is to promote transfer, however, the focus shifts to the other five cognitive processes, *Understand* through *Create*. Of these, arguably the largest category of transfer-based educational objectives emphasized in schools and colleges is *Understand*. Students are said to *Understand* when they are able to construct meaning from instructional messages, including oral, written, and graphic communications, however they are presented to students: during lectures, in books, or on computer monitors. Examples of potential instructional messages include an in-class physics demonstration, a geological formation seen on a field trip, a computer simulation of a trip through an art museum, and a musical work played by an orchestra, as well as numerous verbal, pictorial, and symbolic representations on paper.

Students understand when they build connections between the "new" knowledge to be gained and their prior knowledge. More specifically, the incoming knowledge is integrated with existing schemas and cognitive frameworks. Since concepts are the building blocks for these schemas and frameworks, *Conceptual knowledge* provides a basis for understanding. Cognitive processes in the category of *Understand* include *interpreting, exemplifying, classifying, summarizing, inferring, comparing,* and *explaining*.

2.1 INTERPRETING

Interpreting occurs when a student is able to convert information from one representational form to another. *Interpreting* may involve converting words to words (e.g., paraphrasing), pictures to words, words to pictures, numbers to words, words to numbers, musical notes to tones, and the like.

Alternative terms are translating, paraphrasing, representing, and clarifying.

SAMPLE OBJECTIVES AND CORRESPONDING ASSESSMENTS In *interpreting*, when given information in one form of representation, a student is able to change it into another form. In social studies, for example, an objective could be to learn to paraphrase important speeches and documents from the Civil War period in U.S. history. A corresponding assessment asks a student to paraphrase a famous speech, such as Lincoln's Gettysburg Address. In science, an objective could be to learn to draw pictorial representations of various natural phenomena. A corresponding assessment item asks a student to draw a series of diagrams illustrating photosynthesis. In mathematics, a sample objective could be to learn to translate number sentences expressed in words into algebraic equations expressed in symbols. A corresponding assessment item asks a student to write an equation (using B for the number of boys and G for the number of girls) that corresponds to the statement "There are twice as many boys as girls in this class."

ASSESSMENT FORMATS Appropriate test item formats include both constructed response (i.e., supply an answer) and selected response (i.e., choose an answer). Information is presented in one form, and students are asked either to construct or to select the same information in a different form. For example, a constructed response task is: "Write an equation that corresponds to the following statement, using T for total cost and P for number of pounds. The total cost of mailing a package is \$2.00 for the first pound plus \$1.50 for each additional pound." A selection version of this task is: "Which equation corresponds to the following statement, where T stands for total cost and P for number of pounds? The total cost of mailing a package is \$2.00 for the first pound plus \$1.50 for each additional pound. (a) $T = \$3.50 + P$, (b) $T = \$2.00 + \$1.50(P)$, (c) $T = \$2.00 + \$1.50(P - 1)$."

To increase the probability that *interpreting* rather than *remembering* is being assessed, the information included in the assessment task must be new. "New" here means that students did not encounter it during instruction. Unless this rule is observed, we cannot ensure that *interpreting* rather than *remembering* is being assessed. If the assessment task is identical to a task or example used during instruction, we are probably assessing *remembering*, despite our efforts to the contrary.

Although we will not repeat this point from here on, it applies to each of the process categories and cognitive processes beyond *Remember*. **If assessment tasks are to tap higher-order cognitive processes, they must require that students cannot answer them correctly by relying on memory alone.**

2.2 EXEMPLIFYING

Exemplifying occurs when a student gives a specific example or instance of a general concept or principle. *Exemplifying* involves identifying the defining features of the general concept or principle (e.g., an isosceles triangle must have two equal sides) and using these features to select or construct a specific instance (e.g., being able to select which of three presented triangles is an isosceles triangle). Alternative terms are illustrating and instantiating.

Sample Objectives and Corresponding Assessments In *exemplifying*, a student is given a concept or principle and must select or produce a specific example or instance of it that was not encountered during instruction. In art history, an objective could be to learn to give examples of various artistic painting styles. A corresponding assessment asks a student to select which of four paintings represents the impressionist style. In science, a sample objective could be to be able to give examples of various kinds of chemical compounds. A corresponding assessment task asks the student to locate an inorganic compound on a field trip and tell why it is inorganic (i.e., specify the defining features). In literature, an objective could be to learn to exemplify various play genres. The assessment may give the students brief sketches of four plays (only one of which is a romantic comedy) and ask the student to name the play that is a romantic comedy.

Assessment Formats *Exemplifying* tasks can involve the constructed response format—in which the student must create an example—or the selected response format—in which the student must select an example from a given set. The science example, "Locate an inorganic compound and tell why it is inorganic," requires a constructed response. In contrast, the item "Which of these is an inorganic compound? (a) iron, (b) protein, (c) blood, (d) leaf mold" requires a selected response.

2.3 Classifying

Classifying occurs when a student recognizes that something (e.g., a particular instance or example) belongs to a certain category (e.g., concept or principle). *Classifying* involves detecting relevant features or patterns that "fit" both the specific instance and the concept or principle. *Classifying* is a complementary process to *exemplifying*. Whereas *exemplifying* begins with a general concept or principle and requires the student to find a specific instance or example, *classifying* begins with a specific instance or example and requires the student to find a general concept or principle. Alternative terms for *classifying* are categorizing and subsuming.

Sample Objectives and Corresponding Assessments In social studies, an objective could be to learn to classify observed or described cases of mental disorders. A corresponding assessment item asks a student to observe a video of the behavior of a person with mental illness and then indicate the mental disorder that is displayed. In the natural sciences, an objective could be to learn to categorize the species of various prehistoric animals. An assessment gives a student some pictures of prehistoric animals with instructions to group them with others of the same species. In mathematics, an objective could be to be able to determine the categories to which numbers belong. An assessment task gives an example and asks a student to circle all numbers in a list from the same category.

Assessment Formats In constructed response tasks, a student is given an instance and must produce its related concept or principle. In selected response tasks, a student is given an instance and must select its concept or principle from a list. In a sorting task, a student is given a set of instances and must determine which ones belong in a specified category and which ones do not, or must place each instance into one of multiple categories.

2.4. Summarizing

Summarizing occurs when a student suggests a single statement that represents presented information or abstracts a general theme. *Summarizing* involves constructing a representation of the information, such as the meaning of a scene in a play, and abstracting a summary from it, such as determining a theme or main points. Alternative terms are generalizing and abstracting.

Sample Objectives and Corresponding Assessments In *summarizing*, when given information, a student provides a summary or abstracts a general theme. A sample objective in history could be to learn to write short summaries of events portrayed pictorially. A corresponding assessment item asks a student to watch a videotape on the French Revolution and then write a short summary. Similarly, a sample objective in the natural sciences could be to learn to summarize the major contributions of famous scientists after reading several of their writings. A corresponding assessment item asks a student to read selected writings about Charles Darwin and summarize the major points. In computer science, an objective could be to learn to summarize the purposes of various subroutines in a program. An assessment item presents a program and asks a student to write a sentence describing the subgoal that each section of the program accomplishes within the overall program.

Assessment Formats Assessment tasks can be presented in constructed response or selection formats, involving either themes or summaries. Generally speaking, themes are more abstract than summaries. For example, in a constructed response task, the student may be asked to read an untitled passage on the California Gold Rush and then write an appropriate title. In a selection task, a student may be asked to read a passage on the California Gold Rush and then select the most appropriate title from a list of four possible titles or rank the titles in order of their "fit" to the point of the passage.

2.5 Inferring

Inferring involves finding a pattern within a series of examples or instances. *Inferring* occurs when a student is able to abstract a concept or principle that accounts for a set of examples or instances by encoding the relevant features of each instance and, most important, by noting relationships among them. For example, when given a series of numbers such as 1, 2, 3, 5, 8, 13, 21, a student is able to focus on the numerical value of each digit rather than on irrelevant features such as the shape of each digit or whether each digit is odd or even. He or she then is able to distinguish the pattern in the series of numbers (i.e., after the first two numbers, each is the sum of the preceding two numbers).

The process of *inferring* involves making comparisons among instances within the context of the entire set. For example, to determine what number will come next in the series above, a student must identify the pattern. A related process is using the pattern to create a new instance (e.g., the next number on the series is 34, the sum of 13 and 21). This is an example of *executing,* which is a cognitive process associated with *Apply. Inferring* and *executing* are often used together on cognitive tasks.

Finally, *inferring* is different from *attributing* (a cognitive process associated with *Analyze*). As we discuss later in this chapter, *attributing* focuses solely on the pragmatic issue of determining the author's point of view or intention, whereas *inferring* focuses on the issue of inducing a pattern based on presented information. Another way of differentiating between these two is that *attributing* is broadly applicable to situations in which one must "read between the lines," especially when one is seeking to determine an author's point of view. *Inferring,* on the other hand, occurs in a context that supplies an expectation of what is to be inferred. Alternative terms for *inferring* are extrapolating, interpolating, predicting, and concluding.

SAMPLE OBJECTIVES AND CORRESPONDING ASSESSMENTS In *inferring,* when given a set or series of examples or instances, a student finds a concept or principle that accounts for them. For example, in learning Spanish as a second language, a sample objective could be to be able to infer grammatical principles from examples. For assessment, a student is given the article-noun pairs "la casa, el muchacho, la señorita, el pero" and asked to formulate a principle for when to use "la" and when to use "el." In mathematics, an objective could be to learn to infer the relationship expressed as an equation that represents several observations of values for two variables. An assessment item asks a student to describe the relationship as an equation involving x and y for situations in which if x is 1, then y is 0; if x is 2, then y is 3; and if x is 3, then y is 8.

ASSESSMENT FORMATS Three common tasks that require *inferring* (often along with *implementing*) are completion tasks, analogy tasks, and oddity tasks. In completion tasks, a student is given a series of items and must determine what will come next, as in the number series example above. In analogy tasks, a student is given an analogy of the form A is to B as C is to D, such as "nation" is to "president" as "state" is to ____________. The student's task is to produce or select a term that fits in the blank and completes the analogy (such as "governor"). In an oddity task, a student is given three or more items and must determine which does not belong. For example, a student may be given three physics problems, two involving one principle and another involving a different principle. To focus solely on the inferring process, the question in each assessment task could be to state the underlying concept or principle the student is using to arrive at the correct answer.

2.6 Comparing

Comparing involves detecting similarities and differences between two or more objects, events, ideas, problems, or situations, such as determining how a well-known event (e.g., a recent political scandal) is like a less familiar event (e.g., a historical political scandal). *Comparing* includes finding one-to-one correspondences between elements and patterns in one object, event, or idea and those in another object, event, or idea. When used in conjunction with *inferring* (e.g., first, abstracting a rule from the more familiar situation) and *implementing* (e.g., second, applying the rule to the less familiar situation), *comparing* can contribute to reasoning by analogy. Alternative terms are contrasting, matching, and mapping.

Sample Objectives and Corresponding Assessments In *comparing,* when given new information, a student detects correspondences with more familiar knowledge. For example, in social studies, an objective could be to understand historical events by comparing them to familiar situations. A corresponding assessment question is "How is the American Revolution like a family fight or an argument between friends?" In the natural sciences, a sample objective could be to learn to compare an electrical circuit to a more familiar system. In assessment, we ask "How is an electrical circuit like water flowing through a pipe?"

Comparing may also involve determining correspondences between two or more presented objects, events, or ideas. In mathematics, a sample objective could be to learn to compare structurally similar word problems. A corresponding assessment question asks a student to tell how a certain mixture problem is like a certain work problem.

Assessment Formats A major technique for assessing the cognitive process of *comparing* is mapping. In mapping, a student must show how each part of one object, idea, problem, or situation corresponds to (or maps onto) each part of another. For example, a student could be asked to detail how the battery, wire, and resistor in an electrical circuit are like the pump, pipes, and pipe constructions in a water flow system, respectively.

2.7 Explaining

Explaining occurs when a student is able to construct and use a cause-and-effect model of a system. The model may be derived from a formal theory (as is often the case in the natural sciences) or may be grounded in research or experience (as is often the case in the social sciences and humanities). A complete explanation involves constructing a cause-and-effect model, including each major part in a system or each major event in the chain, and using the model to determine how a change in one part of the system or one "link" in the chain affects a change in another part. An alternative term for *explaining* is constructing a model.

SAMPLE OBJECTIVES AND CORRESPONDING ASSESSMENTS In *explaining,* when given a description of a system, a student develops and uses a cause-and-effect model of the system. For example, in social studies, an objective could be to explain the causes of important eighteenth-century historical events. As an assessment, after reading and discussing a unit on the American Revolution, students are asked to construct a cause-and-effect chain of events that best explains why the war occurred. In the natural sciences, an objective could be to explain how basic physics laws work. Corresponding assessments ask students who have studied Ohm's law to explain what happens to the rate of the current when a second battery is added to a circuit, or ask students who have viewed a video on lightning storms to explain how differences in temperature affect the formation of lightning.

ASSESSMENT FORMATS Several tasks can be aimed at assessing a student's ability to explain, including reasoning, troubleshooting, redesigning, and predicting. In reasoning tasks, a student is asked to offer a reason for a given event. For example, "Why does air enter a bicycle tire pump when you pull up on the handle?" In this case, an answer such as "It is forced in because the air pressure is less inside the pump than outside" involves finding a principle that accounts for a given event.

In troubleshooting, a student is asked to diagnose what could have gone wrong in a malfunctioning system. For example, "Suppose you pull up and press down on the handle of a bicycle tire pump several times but no air comes out. What's wrong?" In this case, the student must find an explanation for a symptom, such as "There is a hole in the cylinder" or "A valve is stuck in the open position."

In redesigning, a student is asked to change the system to accomplish some goal. For example, "How could you improve a bicycle tire pump so that it would be more efficient?" To answer this question, a student must imagine altering one or more of the components in the system, such as "Put lubricant between the piston and the cylinder."

In predicting, a student is asked how a change in one part of a system will effect a change in another part of the system. For example, "What would happen if you increased the diameter of the cylinder in a bicycle tire pump?" This question requires that the student "operate" the mental model of the pump to see that the amount of air moving through the pump could be increased by increasing the diameter of the cylinder.

3. Apply

Apply involves using procedures to perform exercises or solve problems. Thus, *Apply* is closely linked with *Procedural knowledge*. An exercise is a task for which the student already knows the proper procedure to use, so the student has developed a fairly routinized approach to it. A problem is a task for which the student initially does not know what procedure to use, so the student must locate a procedure to solve the problem. The *Apply* category consists of two cognitive processes: *executing*—when the task is an exercise (familiar)—and *implementing*—when the task is a problem (unfamiliar).

When the task is a familiar exercise, students generally know what *Procedural knowledge* to use. When given an exercise (or set of exercises), students typically perform the procedure with little thought. For example, an algebra student confronted with the 50th exercise involving quadratic equations might simply "plug in the numbers and turn the crank."

When the task is an unfamiliar problem, however, students must determine what knowledge they will use. If the task appears to call for *Procedural knowledge* and no available procedure fits the problem situation exactly, then modifications in selected *Procedural knowledge* may be necessary. In contrast to *executing*, then, *implementing* requires some degree of understanding of the problem as well as of the solution procedure. In the case of *implementing*, then, to *understand conceptual knowledge* is a prerequisite to being able to *apply procedural knowledge*.

3.1 Executing

In *executing*, a student routinely carries out a procedure when confronted with a familiar task (i.e., exercise). The familiarity of the situation often provides sufficient clues to guide the choice of the appropriate procedure to use. *Executing* is more frequently associated with the use of skills and algorithms than with techniques and methods (see our discussion of *Procedural knowledge* on pages 52–53). Skills and algorithms have two qualities that make them particularly amenable to *executing*. First, they consist of a sequence of steps that are generally followed *in a fixed order*. Second, when the steps are performed correctly, the end result is a predetermined answer. An alternative term for *executing* is carrying out.

Sample Objectives and Corresponding Assessments In *executing*, a student is faced with a familiar task and knows what to do in order to complete it. The student simply carries out a known procedure to perform the task. For example, a sample objective in elementary level mathematics could be for students to learn to divide one whole number by another, both with multiple digits. The instructions to "divide" signify the division algorithm, which is the necessary *Procedural knowledge*. To assess the objective, a student is given a worksheet that has 15 whole-number division exercises (e.g., 784/15) and is asked to find the quotients. In the natural sciences, a sample objective could be to learn to compute the value of variables using scientific formulas. To assess the objective, a student is given the formula Density = Mass/Volume and must answer the question "What is the density of a material with a mass of 18 pounds and a volume of 9 cubic inches?"

Assessment Formats In *executing*, a student is given a familiar task that can be performed using a well-known procedure. For example, an execution task is "Solve for x: $x^2 + 2x - 3 = 0$ using the technique of completing the square." Students may be asked to supply the answer or, where appropriate, select from among a set of possible answers. Furthermore, because the emphasis is on the procedure as well as the answer, students may be required not only to find the answer but also to show their work.

3.2 Implementing

Implementing occurs when a student selects and uses a procedure to perform an unfamiliar task. Because selection is required, students must possess an understanding of the type of problem encountered as well as the range of procedures that are available. Thus, *implementing* is used in conjunction with other cognitive process categories, such as *Understand* and *Create*.

Because the student is faced with an unfamiliar problem, he or she does not immediately know which of the available procedures to use. Furthermore, no single procedure may be a "perfect fit" for the problem; some modification in the procedure may be needed. *Implementing* is more frequently associated with the use of techniques and methods than with skills and algorithms (see the discussion of *Procedural knowledge* on pages 52–53). Techniques and methods have two qualities that make them particularly amenable to *implementing*. First, the procedure may be more like a "flow chart" than a fixed sequence; that is, the procedure may have "decision points" built into it (e.g., after completing Step 3, should I do Step 4A or Step 4B?). Second, there often is no single, fixed answer that is expected when the procedure is applied correctly.

The notion of no single, fixed answer is especially applicable to objectives that call for *applying conceptual knowledge* such as theories, models, and structures (subtype Cc), where no procedure has been developed for the application. Consider an objective such as "The student shall be able to apply a social psychological theory of crowd behavior to crowd control." Social psychological theory is *Conceptual* not *Procedural knowledge*. This is clearly an *Apply* objective, however, and there is no procedure for making the application. Given that the theory would very clearly structure and guide the student in the application, this objective is just barely on the *Apply* side of *Create*, but *Apply* it is. So it would be classified as *implementing*.

To see why it fits, think of the *Apply* category as structured along a continuum. It starts with the narrow, highly structured *execute*, in which the known *Procedural knowledge* is applied almost routinely. It continues through the broad, increasingly unstructured *implement*, in which, at the beginning, the procedure must be selected to fit a new situation. In the middle of the category, the procedure may have to be modified to *implement* it. At the far end of *implementing*, where there is no set *Procedural knowledge* to modify, a procedure must be manufactured out of *Conceptual knowledge* using theories, models, or structures as a guide. So, although *Apply* is closely linked to *Procedural knowledge*, and this linkage carries through most of the category of *Apply*, there are some instances in *implementing* to which one applies *Conceptual knowledge* as well. An alternative term for *implementing* is using.

SAMPLE OBJECTIVES AND CORRESPONDING ASSESSMENTS In mathematics, a sample objective could be to learn to solve a variety of personal finance problems. A corresponding assessment is to present students with a problem in which they must choose the most economical financing package for a new car. In the natural sciences, a sample objective could be to learn to use the most effective, efficient, and affordable method of conducting a research study to address a specific research question. A corresponding assessment is to give students a research question and have them propose a research study that meets specified criteria of effectiveness, efficiency, and affordability. Notice that in both of these assessment tasks, the student must not only apply a procedure (i.e., engage in *implementing*) but also rely on conceptual understanding of the problem, the procedure, or both.

ASSESSMENT FORMATS In *implementing*, a student is given an unfamiliar problem that must be solved. Thus, most assessment formats begin with specification of the problem. Students are asked to determine the procedure needed to solve the problem, solve the problem using the selected procedure (making modifications as necessary), or usually both.

4. ANALYZE

Analyze involves breaking material into its constituent parts and determining how the parts are related to one another and to an overall structure. This process category includes the cognitive processes of *differentiating*, *organizing*, and *attributing*. Objectives classified as *Analyze* include learning to determine the relevant or important pieces of a message (*differentiating*), the ways in which the pieces of a message are organized (*organizing*), and the underlying purpose of the message (*attributing*). Although learning to *Analyze* may be viewed as an end in itself, it is probably more defensible educationally to consider analysis as an extension of *Understanding* or as a prelude to *Evaluating* or *Creating*.

Improving students' skills in analyzing educational communications is a goal in many fields of study. Teachers of science, social studies, the humanities, and the arts frequently give "learning to analyze" as one of their important objectives. They may, for example, wish to develop in their students the ability to:

- distinguish fact from opinion (or reality from fantasy);
- connect conclusions with supporting statements;

- distinguish relevant from extraneous material;
- determine how ideas are related to one another;
- ascertain the unstated assumptions involved in what is said;
- distinguish dominant from subordinate ideas or themes in poetry or music; and
- find evidence in support of the author's purposes.

The process categories of *Understand, Analyze,* and *Evaluate* are interrelated and often used iteratively in performing cognitive tasks. At the same time, however, it is important to maintain them as separate process categories. A person who understands a communication may not be able to analyze it well. Similarly, someone who is skillful in analyzing a communication may evaluate it poorly.

4.1 Differentiating

Differentiating involves distinguishing the parts of a whole structure in terms of their relevance or importance. *Differentiating* occurs when a student discriminates relevant from irrelevant information, or important from unimportant information, and then attends to the relevant or important information. *Differentiating* is different from the cognitive processes associated with *Understand* because it involves structural organization and, in particular, determining how the parts fit into the overall structure or whole. More specifically, *differentiating* differs from *comparing* in using the larger context to determine what is relevant or important and what is not. For instance, in *differentiating* apples and oranges in the context of fruit, internal seeds are relevant, but color and shape are irrelevant. In *comparing,* all of these aspects (i.e., seeds, color, and shape) are relevant. Alternative terms for *differentiating* are discriminating, selecting, distinguishing, and focusing.

Sample Objectives and Corresponding Assessments In the social sciences, an objective could be to learn to determine the major points in research reports. A corresponding assessment item requires a student to circle the main points in an archeological report about an ancient Mayan city (such as when the city began and when it ended, the population of the city over the course of its existence, the geographic location of the city, the physical buildings in the city, its economic and cultural function, the social organization of the city, why the city was built and why it was deserted).

Similarly, in the natural sciences, an objective could be to select the main steps in a written description of how something works. A corresponding assessment item asks a student to read a chapter in a book that describes lightning formation and then to divide the process into major steps (including moist air rising to form a cloud, creation of updrafts and downdrafts inside the cloud, separation of charges within the cloud, movement of a stepped leader downward from cloud to ground, and creation of a return stroke from ground to cloud).

Finally, in mathematics, an objective could be to distinguish between relevant and irrelevant numbers in a word problem. An assessment item requires a student to circle the relevant numbers and cross out the irrelevant numbers in a word problem.

Assessment Formats *Differentiating* can be assessed with constructed response or selection tasks. In a constructed response task, a student is given some material and is asked to indicate which parts are most important or relevant, as in this example: "Write the numbers that are needed to solve this problem: Pencils come in packages that contain 12 each and cost $2.00 each. John has $5.00 and wishes to buy 24 pencils. How many packages does he need to buy?" In a selection task, a student is given some material and is asked to choose which parts are most important or relevant, as in this example: "Which numbers are needed to solve this problem? Pencils come in packages that contain 12 each and cost $2.00 each. John has $5.00 and wishes to buy 24 pencils. How many packages does he need to buy? (a) 12, $2.00, $5.00, 24; (b) 12, $2.00, $5.00; (c) 12, $2.00, 24; (d) 12, 24."

4.2 Organizing

Organizing involves identifying the elements of a communication or situation and recognizing how they fit together into a coherent structure. In *organizing,* a student builds systematic and coherent connections among pieces of presented information. *Organizing* usually occurs in conjunction with *differentiating*. The student first identifies the relevant or important elements and then determines the overall structure within which the elements fit. *Organizing* can also occur in conjunction with *attributing,* in which the focus is on determining the author's intention or point of view. Alternative terms for *organizing* are structuring, integrating, finding coherence, outlining, and parsing.

Sample Objectives and Corresponding Assessments In *organizing,* when given a description of a situation or problem, a student is able to identify the systematic, coherent relationships among relevant elements. A sample objective in social studies could be to learn to structure a historical description into evidence for and against a particular explanation. A corresponding assessment item asks a student to write an outline that shows which facts in a passage on American history support and which facts do not support the conclusion that the American Civil War was caused by differences in the rural and urban composition of the North and South. A sample objective in the natural sciences could be to learn to analyze research reports in terms of four sections: hypothesis, method, data, and conclusion. As an assessment, students are asked to produce an outline of a presented research report. In mathematics, a sample objective could be to learn to outline textbook lessons. A corresponding assessment task asks a student to read a textbook lesson on basic statistics and then generate a matrix that includes each statistic's name, formula, and the conditions under which it is used.

ASSESSMENT FORMATS *Organizing* involves imposing a structure on material (such as an outline, table, matrix, or hierarchical diagram). Thus, assessment can be based on constructed response or selection tasks. In a constructed response task, a student may be asked to produce a written outline of a passage. In a selection task, a student may be asked to select which of four alternative graphic hierarchies best corresponds to the organization of a presented passage.

4.3 ATTRIBUTING

Attributing occurs when a student is able to ascertain the point of view, biases, values, or intention underlying communications. *Attributing* involves a process of deconstruction, in which a student determines the intentions of the author of the presented material. In contrast to *interpreting,* in which the student seeks to *Understand* the meaning of the presented material, *attributing* involves an extension beyond basic understanding to infer the intention or point of view underlying the presented material. For example, in reading a passage on the battle of Atlanta in the American Civil War, a student needs to determine whether the author takes the perspective of the North or the South.
An alternative term is deconstructing.

SAMPLE OBJECTIVES AND CORRESPONDING ASSESSMENTS In *attributing,* when given information, a student is able to determine the underlying point of view or intention of the author. For example, in literature, an objective could be to learn to determine the motives for a series of actions by characters in a story. A corresponding assessment task for the students having read Shakespeare's *Macbeth* is to ask what motive(s) Shakespeare attributed to Macbeth for the murder of King Duncan. In social studies, a sample objective could be to learn to determine the point of view of the author of an essay on a controversial topic in terms of his or her theoretical perspective. A corresponding assessment task asks a student whether a report on Amazon rain forests was written from a pro-environment or pro-business point of view. This objective is also applicable to the natural sciences. A corresponding assessment task asks a student to determine whether a behaviorist or a cognitive psychologist wrote an essay about human learning.

ASSESSMENT FORMATS *Attributing* can be assessed by presenting some written or oral material and then asking a student to construct or select a description of the author's or speaker's point of view, intentions, and the like. For example, a constructed response task is "What is the author's purpose in writing the essay you read on the Amazon rain forests?" A selection version of this task is "The author's purpose in writing the essay you read is to: (a) provide factual information about Amazon rain forests, (b) alert the reader to the need to protect rain forests, (c) demonstrate the economic advantages of developing rain forests, or (d) describe the consequences to humans if rain forests are developed." Alternatively, students might be asked to indicate whether the author of the essay would (a) strongly agree, (b) agree, (c) neither agree nor disagree, (d) disagree, or (e) strongly disagree with several statements. Statements like "The rainforest is a unique type of ecological system" would follow.

5. EVALUATE

Evaluate is defined as making judgments based on criteria and standards. The criteria most often used are quality, effectiveness, efficiency, and consistency. They may be determined by the student or by others. The standards may be either quantitative (i.e., Is this a sufficient amount?) or qualitative (i.e., Is this good enough?). The standards are applied to the criteria (e.g., Is this process sufficiently effective? Is this product of sufficient quality?). The category *Evaluate* includes the cognitive processes of *checking* (judgments about the internal consistency) and *critiquing* (judgments based on external criteria).

It must be emphasized that not all judgments are evaluative. For example, students make judgments about whether a specific example fits within a category. They make judgments about the appropriateness of a particular procedure for a specified problem. They make judgments about whether two objects are similar or different. Most of the cognitive processes, in fact, require some form of judgment. What most clearly differentiates *Evaluate* as defined here from other judgments made by students is the use of standards of performance with clearly defined criteria. Is this machine working as efficiently as it should be? Is this method the best way to achieve the goal? Is this approach more cost effective than other approaches? Such questions are addressed by people engaged in *Evaluating*.

5.1 CHECKING

Checking involves testing for internal inconsistencies or fallacies in an operation or a product. For example, *checking* occurs when a student tests whether or not a conclusion follows from its premises, whether data support or disconfirm a hypothesis, or whether presented material contains parts that contradict one another. When combined with *planning* (a cognitive process in the category *Create*) and *implementing* (a cognitive process in the category *Apply*), checking involves determining how well the plan is working. Alternative terms for *checking* are testing, detecting, monitoring, and coordinating.

SAMPLE OBJECTIVES AND CORRESPONDING ASSESSMENTS In *checking*, students look for internal inconsistencies. A sample objective in the social sciences could be to learn to detect inconsistencies in persuasive messages. A corresponding assessment task asks students to watch a television advertisement for a political candidate and point out any logical flaws in the persuasive message. A sample objective in the sciences could be to learn to determine whether a scientist's conclusion follows from the observed data. An assessment task asks a student to read a report of a chemistry experiment and determine whether or not the conclusion follows from the results of the experiment.

Assessment Formats *Checking* tasks can involve operations or products given to the students or ones created by the students themselves. *Checking* can also take place within the context of carrying out a solution to a problem or performing a task, where one is concerned with the consistency of the actual implementation (e.g., Is this where I should be in light of what I've done so far?).

5.2 Critiquing

Critiquing involves judging a product or operation based on externally imposed criteria and standards. In *critiquing*, a student notes the positive and negative features of a product and makes a judgment based at least partly on those features. *Critiquing* lies at the core of what has been called critical thinking. An example of *critiquing* is judging the merits of a particular solution to the problem of acid rain in terms of its likely effectiveness and its associated costs (e.g., requiring all power plants throughout the country to restrict their smokestack emissions to certain limits). An alternative term is judging.

Sample Objectives and Corresponding Assessments In *critiquing*, students judge the merits of a product or operation based on specified or student-determined criteria and standards. In the social sciences, an objective could be to learn to evaluate a proposed solution (such as "eliminate all grading") to a social problem (such as "how to improve K–12 education") in terms of its likely effectiveness. In the natural sciences, an objective could be to learn to evaluate the reasonableness of a hypothesis (such as the hypothesis that strawberries are growing to extraordinary size because of the unusual alignment of the stars). Finally, in mathematics, an objective could be to learn to judge which of two alternative methods is a more effective and efficient way of solving given problems (such as judging whether it is better to find all prime factors of 60 or to produce an algebraic equation to solve the problem "What are the possible ways you could multiply two whole numbers to get 60?").

Assessment Formats A student may be asked to critique his or her own hypotheses or creations or those generated by someone else. The critique could be based on positive, negative, or both kinds of criteria and yield both positive and negative consequences. For example, in *critiquing* a school district's proposal for year-round schools, a student would generate positive consequences, such as the elimination of learning loss over summer vacation, and negative consequences, such as disruption of family vacations.

6. Create

Create involves putting elements together to form a coherent or functional whole. Objectives classified as *Create* have students make a new product by mentally reorganizing some elements or parts into a pattern or structure not clearly present before. The processes involved in *Create* are generally coordinated with the student's previous learning experiences. Although *Create* requires creative thinking on the part of the student, this is not completely free creative expression unconstrained by the demands of the learning task or situation.

To some persons, creativity is the production of unusual products, often as a result of some special skill. *Create,* as used here, however, although it includes objectives that call for unique production, also refers to objectives calling for production that all students can and will do. If nothing else, in meeting these objectives, many students will create in the sense of producing their own synthesis of information or materials to form a new whole, as in writing, painting, sculpting, building, and so on.

Although many objectives in the *Create* category emphasize originality (or uniqueness), educators must define what is original or unique. Can the term *unique* be used to describe the work of an individual student (e.g., "This is unique for Adam Jones") or is it reserved for use with a group of students (e.g., "This is unique for a fifth-grader")? It is important to note, however, that many objectives in the *Create* category do not rely on originality or uniqueness. The teachers' intent with these objectives is that students should be able to synthesize material into a whole. This synthesis is often required in papers in which the student is expected to assemble previously taught material into an organized presentation.

Although the process categories of *Understand, Apply,* and *Analyze* may involve detecting relationships among presented elements, *Create* is different because it also involves the construction of an original product. Unlike *Create,* the other categories involve working with a given set of elements that are part of a given whole; that is, they are part of a larger structure the student is trying to understand. In *Create,* on the other hand, the student must draw upon elements from many sources and put them together into a novel structure or pattern relative to his or her own prior knowledge. *Create* results in a new product, that is, something that can be observed and that is more than the student's beginning materials. A task that requires *Create* is likely to require aspects of each of the earlier cognitive process categories to some extent, but not necessarily in the order in which they are listed in the Taxonomy Table.

We recognize that composition (including writing) often, but not always, requires the cognitive processes associated with *Create*. For example, *Create* is not involved in writing that represents the remembering of ideas or the interpretation of materials. We also recognize that deep understanding that goes beyond basic understanding can require the cognitive processes associated with *Create.* To the extent that deep understanding is an act of construction or insight, the cognitive processes of *Create* are involved.

The creative process can be broken into three phases: problem representation, in which a student attempts to understand the task and generate possible solutions; solution planning, in which a student examines the possibilities and devises a workable plan; and solution execution, in which a student successfully carries out the plan. Thus, the creative process can be thought of as starting with a divergent phase in which a variety of possible solutions are considered as the student attempts to understand the task (*generating*). This is followed by a convergent phase, in which the student devises a solution method and turns it into a plan of action (*planning*). Finally, the plan is executed as the student constructs the solution (*producing*). It is not surprising, then, that *Create* is associated with three cognitive processes: *generating*, *planning*, and *producing*.

6.1 GENERATING

Generating involves representing the problem and arriving at alternatives or hypotheses that meet certain criteria. Often the way a problem is initially represented suggests possible solutions; however, redefining or coming up with a new representation of the problem may suggest different solutions. When *generating* transcends the boundaries or constraints of prior knowledge and existing theories, it involves divergent thinking and forms the core of what can be called creative thinking.

Generating is used in a restricted sense here. *Understand* also requires generative processes, which we have included in *translating*, *exemplifying*, *summarizing*, *inferring*, *classifying*, *comparing*, and *explaining*. However, the goal of *Understand* is most often convergent (that is, to arrive at a single meaning). In contrast, the goal of *generating* within *Create* is divergent (that is, to arrive at various possibilities). An alternative term for *generating* is hypothesizing.

SAMPLE OBJECTIVE AND CORRESPONDING ASSESSMENT In *generating*, a student is given a description of a problem and must produce alternative solutions. For example, in the social sciences, an objective could be to learn to generate multiple useful solutions for social problems. A corresponding assessment item is: "Suggest as many ways as you can to assure that everyone has adequate medical insurance." To assess student responses, the teacher should construct a set of criteria that are shared with the students. These might include the number of alternatives, the reasonableness of the various alternatives, the practicality of the various alternatives, and so on. In the natural sciences, an objective could be to learn to generate hypotheses to explain observed phenomena. A corresponding assessment task asks students to write as many hypotheses as they can to explain strawberries growing to extraordinary size. Again, the teacher should establish clearly defined criteria for judging the quality of the responses and give them to the students. Finally, an objective from the field of mathematics could be to be able to generate alternative methods for achieving a particular result. A corresponding assessment item is: "What alternative methods could you use to find what whole numbers yield 60 when multiplied together?" For each of these assessments, explicit, publicly shared scoring criteria are needed.

ASSESSMENT FORMATS Assessing *generating* typically involves constructed response formats in which a student is asked to produce alternatives or hypotheses. Two traditional subtypes are consequences tasks and uses tasks. In a consequences task, a student must list all the possible consequences of a certain event, such as "What would happen if there was a flat income tax rather than a graduated income tax?" In a uses task, a student must list all possible uses for an object, such as "What are the possible uses for the World Wide Web?" It is almost impossible to use the multiple-choice format to assess *generating* processes.

6.2 PLANNING

Planning involves devising a solution method that meets a problem's criteria, that is, developing a plan for solving the problem. *Planning* stops short of carrying out the steps to create the actual solution for a given problem. In *planning,* a student may establish subgoals, or break a task into subtasks to be performed when solving the problem. Teachers often skip stating *planning* objectives, instead stating their objectives in terms of *producing,* the final stage of the creative process. When this happens, *planning* is either assumed or implicit in the *producing* objective. In this case, *planning* is likely to be carried out by the student covertly during the course of constructing a product (i.e., *producing*). An alternative term is designing.

SAMPLE OBJECTIVES AND CORRESPONDING ASSESSMENTS In *planning,* when given a problem statement, a student develops a solution method. In history, a sample objective could be to be able to plan research papers on given historical topics. An assessment task asks the student, prior to writing a research paper on the causes of the American Revolution, to submit an outline of the paper, including the steps he or she intends to follow to conduct the research. In the natural sciences, a sample objective could be to learn to design studies to test various hypotheses. An assessment task asks students to plan a way of determining which of three factors determines the rate of oscillation of a pendulum. In mathematics, an objective could be to be able to lay out the steps needed to solve geometry problems. An assessment task asks students to devise a plan for determining the volume of the frustrum of a pyramid (a task not previously considered in class). The plan may involve computing the volume of the large pyramid, then computing the volume of the small pyramid, and finally subtracting the smaller volume from the larger.

ASSESSMENT FORMATS *Planning* may be assessed by asking students to develop worked-out solutions, describe solution plans, or select solution plans for a given problem.

6.3 PRODUCING

Producing involves carrying out a plan for solving a given problem that meets certain specifications. As we noted earlier, objectives within the category *Create* may or may not include originality or uniqueness as one of the specifications. So it is with *producing* objectives. *Producing* can require the coordination of the four types of knowledge described in Chapter 4. An alternative term is constructing.

Sample Objectives and Corresponding Assessments In *producing*, a student is given a functional description of a goal and must create a product that satisfies the description. It involves carrying out a solution plan for a given problem. Sample objectives involve producing novel and useful products that meet certain requirements. In history, an objective could be to learn to write papers pertaining to particular historical periods that meet specified standards of scholarship. An assessment task asks students to write a short story that takes place during the American Revolution. In science, an objective could be to learn to design habitats for certain species and certain purposes. A corresponding assessment task asks students to design the living quarters of a space station. In English literature, an objective could be to learn to design sets for plays. A corresponding assessment task asks students to design the set for a student production of *Driving Miss Daisy*. In all these examples, the specifications become the criteria for evaluating student performance relative to the objective. These specifications, then, should be included in a scoring rubric that is given to the students in advance of the assessment.

Assessment Formats A common task for assessing *producing* is a design task, in which students are asked to create a product that corresponds to certain specifications. For example, students may be asked to produce schematic plans for a new high school that include new ways for students to conveniently store their personal belongings.

Decontextualized and Contextualized Cognitive Processes

We have examined each cognitive process in isolation (i.e., as decontextualized processes). In the next section we examine the processes within the context of a particular educational objective (i.e., as contextualized processes). In this way, we are reuniting cognitive processes with knowledge. Unlike decontextualized processes (e.g., planning), contextualized processes occur within a specific academic context (e.g., planning the composition of a literary essay, planning to solve an arithmetic word problem, or planning to perform a scientific experiment).

Although it may be easier to focus on decontextualized cognitive processes, two findings from research in cognitive science point to the important role of context in learning and thinking (Bransford, Brown, and Cocking, 1999; Mayer, 1992; Smith, 1991). First, research suggests that the nature of the cognitive process depends on the subject matter to which it is applied (Bruer, 1993; Mayer, 1999; Pressley and Woloshyn, 1995). For example, learning to plan solutions to mathematics problems is different from learning to plan the composition of literary essays. Consequently, experience in planning in mathematics does not necessarily help a student learn to plan essay compositions. Second, research on authentic assessment suggests that the nature of a process depends on the authenticity of the task to which it is applied (Baker, O'Neil, and Linn, 1993; Hambleton, 1996). For example, learning to generate writing plans (without actually writing an essay) is different from learning to generate plans within the context of actually producing an essay.

Although we have described the cognitive processes individually, they are likely to be used in coordination with one another to facilitate meaningful school learning. Most authentic academic tasks require the coordinated use of several cognitive processes as well as several types of knowledge. For example, to solve a mathematical word problem, a student may engage in:

- *interpreting* (to understand each sentence in the problem);
- *recalling* (to retrieve the relevant *Factual knowledge* needed to solve the problem);
- *organizing* (to build a coherent representation of the key information in the problem, that is, *Conceptual knowledge*);
- *planning* (to devise a solution plan); and
- *producing* (to carry out the plan, that is, *Procedural knowledge*) (Mayer, 1992).

Similarly, to write an essay, a student may engage in:

- *recalling* (to retrieve relevant information that may be included in the essay);
- *planning* (to decide what to include in the essay, determine what to say, and how to say it);
- *producing* (to create a written product); and
- *critiquing* (to make sure the written essay "makes sense") (Levy and Ransdell, 1996).

An Example of Educational Objectives in Context

In simplest terms, our revised framework is intended to help teachers teach, learners learn, and assessors assess. Suppose, for example, that a teacher has a very general objective for her students: She wants them to learn about Ohm's law. She devises an instructional unit accordingly. Because of the vagueness of the objective, this unit potentially includes all four types of knowledge: *Factual, Conceptual, Procedural,* and *Metacognitive*. An example of *Factual knowledge* is that current is measured in amps, voltage in volts, and resistance in ohms. An example of *Procedural knowledge* is the steps involved in using the formula for Ohm's law (voltage = current × resistance) to compute a numerical value.

Although these two types of knowledge are the most obvious to include in this unit, a deeper understanding of Ohm's law requires the other two types of knowledge: *Conceptual* and *Metacognitive*. An example of *Conceptual knowledge* is the structure and workings of an electrical circuit that consists of batteries, wires, and a light bulb. An electrical circuit is a conceptual system in which there are causal relations among the elements (e.g., if more batteries are added in serial, the voltage increases, which causes an increase in the flow of electrons in the wires as measured by an increase in current). As an example of *Metacognitive knowledge,* the teacher may intend students to know when to use mnemonic strategies for memorizing the name of the law, the formula, and similar relevant items. She also may want them to establish their own goals for learning Ohm's law and its applications.

Remembering What Was Learned

A restricted set of objectives for the unit on Ohm's law could focus solely on promoting retention. Objectives for promoting retention are based primarily on the cognitive process category *Remember,* which includes *recalling* and *recognizing factual, procedural, conceptual,* and *metacognitive knowledge.* For example, an objective for *recalling factual knowledge* is that students will be able to *recall* what the letters stand for in the formula for Ohm's law. An objective for *recalling procedural knowledge* is that students will be able to *recall* the steps involved in applying Ohm's law.

Although these are the obvious kinds of retention-type objectives to include in the unit, it is also possible to develop retention-type objectives that involve *Conceptual* and *Metacognitive knowledge*. For *Conceptual knowledge,* an objective is that students will be able to draw, from memory, a picture of an electrical circuit. Because this objective focuses on *recalling,* each student's drawing is evaluated in terms of how closely it corresponds to a picture presented in the textbook or previously on the chalkboard. Students may answer questions about *Conceptual* and *Metacognitive knowledge* in a rote manner, relying exclusively on previously presented material. When the overall purpose of the unit is to promote transfer of learning, *Remember* objectives need to be supplemented with objectives that involve more complex cognitive processes.

Finally, an objective pertaining to *recalling metacognitive knowledge* is that students remember "When stuck in a hole, stop digging." In other words, when their first approach to solving a problem or arriving at an answer is not succeeding, they remember to stop and assess other possible approaches. Again, with the emphasis on *Remember,* students may be queried about whether, when their first approach to a problem bogged down, they remembered the slogan. If student answers are being graded, students will give the response they know the teacher desires (i.e., "Of course, I did"), so this assessment task works only where students realize its purpose is to help them improve their learning.

Making Sense of and Using What Was Learned

When the concern of the teacher turns to promoting transfer, he or she needs to consider the full range of cognitive process categories. Consider the myriad of possibilities inherent in the following list:

- An objective for *interpreting factual knowledge*: "Students should be able to define key terms (e.g., *resistance*) in their own words."
- An objective for *explaining conceptual knowledge*: "Students should be able to explain what happens to the rate of current in an electrical circuit when changes are made in the system (e.g., two batteries that were connected in serial are reconnected in parallel)."
- An objective for *executing procedural knowledge*: "The student will be able to use Ohm's law to compute the voltage when given the current (in amperes) and the resistance (in ohms)."
- An objective for *differentiating conceptual knowledge*: "The student will be able to determine which information in word problems involving Ohm's

law (e.g., wattage of light bulb, thickness of wire, voltage of battery) is needed to determine the resistance."

- An objective for *checking procedural knowledge*: "The student will be able to determine whether a worked-out solution to a problem involving Ohm's law is likely to be effective in solving it."
- An objective for *critiquing metacognitive knowledge*: "The student will be able to choose a plan for solving problems involving Ohm's law that is most consistent with his or her current level of understanding."
- An objective for *generating conceptual knowledge*: "The student will be able to generate alternative ways of increasing the brightness of the light in a circuit without changing the battery."

We can summarize the entire set of objectives in this instructional unit on Ohm's law using the Taxonomy Table (see Table 5.2). The Xs indicate objectives that are included in this unit based on the examples we gave. Not all cells are filled; thus, not all possible combinations of cognitive process and knowledge are included in the unit. Nonetheless, it is clear that the unit includes a variety of objectives that go beyond *remember factual knowledge.* Our focus on objectives in instructional units suggests that the most effective way of teaching and assessing educational objectives may be to embed them within a few basic contexts (such as an instructional unit) rather than to focus on each in isolation. We return to this theme later.

Conclusion

A major goal of this chapter is to examine how teaching and assessing can be broadened beyond an exclusive focus on the cognitive process *Remember*. We described 19 specific cognitive processes associated with six process categories. Two of these cognitive processes are associated with *Remember*; 17 are associated with the process categories beyond it: *Understand, Apply, Analyze, Evaluate,* and *Create.*

Our analysis has implications for both teaching and assessing. On the teaching side, two of the cognitive processes help to promote retention of learning, whereas 17 of them help to foster transfer of learning. Thus, when the goal of instruction is to promote transfer, objectives should include the cognitive processes associated with *Understand, Apply, Analyze, Evaluate,* and *Create*. The descriptions in this chapter are intended to help educators generate a broader range of educational objectives that are likely to result in both retention and transfer.

On the assessment side, our analysis of cognitive processes is intended to help educators (including test designers) broaden their assessments of learning. When the goal of instruction is to promote transfer, assessment tasks should tap cognitive processes that go beyond remembering. Although assessment tasks that tap *recalling* and *recognizing* have a place in assessment, these tasks can (and often should) be supplemented with those that tap the full range of cognitive processes required for transfer of learning.

5.2 Completed Taxonomy Table for Hypothetical Ohm's Law Unit

The Knowledge Dimension	The Cognitive Process Dimension					
	1. Remember	2. Understand	3. Apply	4. Analyze	5. Evaluate	C
A. Factual knowledge	X	X				
B. Conceptual knowledge	X	X		X		
C. Procedural knowledge	X		X		X	
D. Meta-cognitive knowledge	X				X	