In devising effective instruction, the goal is to provide learning experiences (i.e., instructional manipulations) that are appropriate for the learner (i.e., learner characteristics) and learning situation (i.e., learning context), that will prime appropriate cognitive processing in the learner (i.e., learning processes) that lead to the construction of knowledge (i.e., learning outcome), which is indicated by a change in the learner's behavior (i.e., outcome performance).

THREE KINDS OF LEARNING OUTCOMES

Based on the cognitive model of meaningful learning in Figure 1–3 and the cognitive model of instruction in Table 1–7, we can pinpoint the cognitive conditions that lead to meaningful learning. For example, let's suppose that we ask students to read a short lesson on how lightning occurs. Then we give them a retention test to measure how much of the presented information they remember, and a transfer test, to measure how well they can creatively apply what they learned to solve new problems. The retention test could include items such as, "A lightning flash lasts about ______ microseconds" or "The amount of electrical potential in a lightning flash is ______ volts." The transfer test could ask, "How could you decrease the intensity of lightning?"

Some students will not remember much from the lesson and will not be able to answer transfer questions. These students could be called nonlearners. Some students will remember much of the information but will not be able to creatively use the information to solve problems or make explanations. These students could be called rote learners (or nonunderstanders). Finally, some might be able to remember information and to use that information creatively in solving novel problems. They are meaningful learners (or understanders). Table 1–8 summarizes the differences in the performance among these three types of learners.

What conditions of learning create each of these kinds of outcomes? Gagne (1974) made a useful distinction between two conditions of learning: internal conditions refer to the cognitive processes that are activated inside the learner at the time of learning; external conditions refer to the instructional events that occur outside the learner.

Mayer (1996b, 2001b) suggested that three major internal conditions must be met for instruction to foster meaningful learning: Instruction must help the learner select relevant information, organize information, and integrate information, as summarized in Figure 1–4. As you can see, three scenarios can be generated:

Nonlearning: If the first condition is not met, nothing will be learned. Thus, even when a student may be actively thinking about all he or she knows about lightning, nothing

TABLE 1–8

Three kinds of learners

Type of Learner	Retention Performance	Transfer Performance
Nonlearner	Poor	Poor
Nonunderstander	Good	Poor
Understander	Good	Good

Adapted from Mayer (1984).

will be learned if the student fails to carefully read the passage. This result is indicated by poor retention and poor transfer performance.

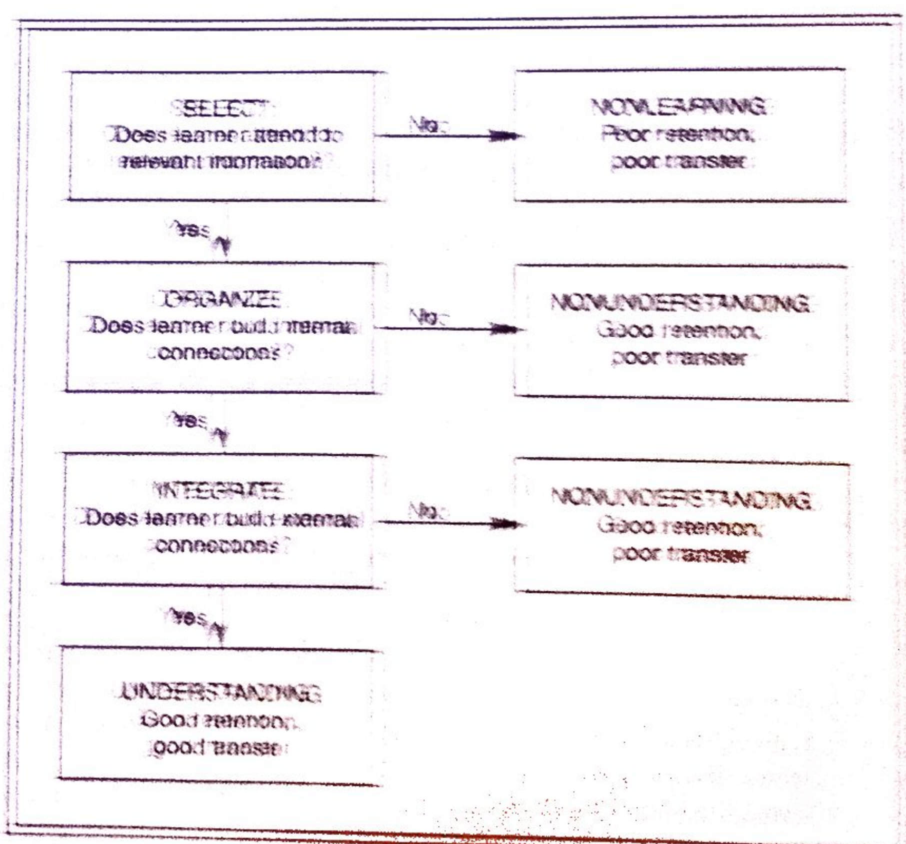
Rote learning: If the first condition is met, but the second or third condition is not met, then the student will learn in a nonmeaningful way. For example, in reading a passage on lightning, the second condition would be lacking if the learner fails to create a cause-and-effect chain among events in the process of lightning. Similarly, the third condition would be missing if the learner does not possess or activate relevant existing knowledge (e.g., the ideas of temperature imbalance and electrical imbalance), so the material is not well integrated with existing knowledge. This result is indicated by good retention and poor transfer performance.

Meaningful learning: If all three conditions are met, then the student will learn in a meaningful way. For example, the new information about lightning will be organized into a coherent cause-and-effect structure and integrated with existing knowledge about temperature and electrical imbalances. The result is manifested in good retention and transfer performance.

Although these distinctions are much too vague to qualify as a theory of instruction, they do provide a framework for describing different kinds of learning situations. The main theme, of course, is that meaningful learning depends on active cognitive processing during learning—that is, on the active construction of knowledge.

FIGURE 1–4

The three major conditions of meaningful learning



In addition, three external conditions required for instruction to foster meaningful learning are that the material is potentially meaningful, the learner needs help, and the test evaluates meaningful learning. If the material is not understandable—such as a random list of unconnected facts—no type of instruction can help the learner make sense out of it. If the learner already knows how to select, organize, and integrate information in a lesson, then instruction aimed at inducing the learner to use these processes is not needed. Finally, if the test simply measures overall amount retained, it is not possible to show that meaningful learning occurred.

THREE KINDS OF COGNITIVE LOAD

Cognitive load theory is based on the idea that cognitive capacity for learning is limited and that there are three main sources of cognitive load during learning: intrinsic cognitive load, extraneous cognitive load, and germane cognitive load (Paas, Renkl, Sweller, 2003; Sweller, 1999).

Intrinsic cognitive load: refers to the amount of cognitive processing required to comprehend the to-be-learned material and depends on its conceptual complexity. Intrinsic load is reflected in the cognitive process of selecting relevant elements and relations for further processing (as shown in Figure 1–3). Sweller (1999) defines intrinsic load in terms of element interactivity: Material with high element interactivity has many elements that interact one another (such as an explanation of how a complex system works) and requires more cognitive capacity, whereas material with low element interactivity consists of elements that can be learned independently (such as the definitions of a collection of words) and requires less cognitive capacity. Intrinsic cognitive load cannot be eliminated, but it can be managed through effective instruction—such as breaking a lesson into bite-sized segments or giving pretraining in the name and characteristics of each major element (Mayer, 2005b).

Extraneous cognitive load: refers to the amount of cognitive capacity used for cognitive processing that is not relevant to the goals of instruction. Extraneous load occurs when a lesson is poorly designed, such as when instruction is disorganized or contains a lot of extraneous material. Extraneous cognitive load can be reduced through effective instructional design—such as reducing the amount of extraneous information, using headings that signal the organization of the material, and placing pictures near the words that describe them (Mayer, 2005c).

Germane cognitive load: occurs when learners engage in deep cognitive processing of the to-be-learned material, as reflected in the cognitive process of organizing and integrating. Germane cognitive processing can be fostered by asking the learner to engage in activities such as self-explaining (i.e., explaining the material to oneself) or by presenting the material in a friendly, conversational style (Mayer, 2005d).

The relevance of cognitive load theory for instruction is that instruction should be designed to manage intrinsic load, minimize extraneous load, and promote germane load (Mayer & Moreno, 2003; Sweller, 2005). If the learner must waste cognitive resources on extraneous processing, then the learner may not have sufficient capacity remaining for intrinsic and germane processing. Table 1–9 summarizes the three kinds of cognitive load.

TABLE 1–9
Three sources of cognitive load during learning

Name	Description	Cognitive Processing	Instructional Implications
Intrinsic	Due to conceptual complexity of material	Initial processing to begin comprehending the material (i.e., selecting)	Manage by segmenting or pretraining
Extraneous	Due to poor instructional design	Processing not relevant to learning (i.e., scanning)	Reduce by cutting out extraneous material, using headings to signal organization, and placing words near corresponding pictures
Germane	Due to effort in sense making	Deep processing of the material (i.e., organizing and integrating)	Foster by using conversational style and encouraging self-explanation

Sources: Based on Sweller (1999) and Mayer and Moreno (2003).

The Challenge of Teaching for Transfer

Perhaps the central goal of education is to promote meaningful learning—learning in which the learner engages in active cognitive processing that leads to transfer. If your goal is to teach in ways that enable transfer, it is useful to explore the nature of transfer and its somewhat disappointing history in education.

WHAT IS TRANSFER?

Transfer is the effect of previous learning on new learning or problem solving. This definition yields two types of transfer—transfer of learning and problem-solving transfer. *Transfer of learning* (or learning transfer) is the effect of previous learning on new learning. It occurs successfully when a person uses knowledge from previous experience to help learn something new. *Problem-solving transfer* is the effect of previous learning on new problem solving. Problem-solving transfer occurs successfully when a person uses knowledge from previous experience to devise a solution to a new problem (Mayer & Wittrock, 1996). In this book, I focus mainly on problem-solving transfer, that is, the ability to use what you have learned when you are faced with a new problem. Transfer can be positive, negative, or neutral. Positive transfer occurs when previous learning helps new problem solving or learning; negative transfer occurs when previous learning hurts new problem solving or learning; and neutral transfer occurs when previous learning has no effect on new problem solving or learning. Figure 1–5 shows one way to test for transfer in which some people learn A and then are asked to solve problem B (experimental group), whereas other people do not learn A and then are asked to solve problem B (control group). If the experimental group outperforms the control group on B, positive transfer occurred; if the control group outperforms

FIGURE 1–5 Testing for transfer

Group	Learning Task	Transfer Task
Experimental group	A	B
Control group	—	B

Type of Transfer	Performance on Transfer Task
Positive transfer	Experimental group outperforms control group
Negative transfer	Control group outperforms experimental group
Neutral transfer	Experimental and control groups are equivalent

the experimental group on B, then negative transfer occurred; and if the two groups perform similarly on B, then there is neutral transfer. For example, you might expect positive transfer if someone learns how to use a word processor and then needs to use it to write a business letter. You might expect some negative transfer if a person learned to use one kind of word processor and then had to write a business letter using a different kind. My focus in this book, of course, is on how to promote positive transfer.

Transfer can be specific, general, or mixed, as shown in Table 1–10. Specific transfer means that elements in A are identical to B; for example, you learn how to add and subtract single-digit numbers, and then you try to solve some two-digit addition and subtraction problems. Some of the steps are the same in both procedures, such as knowing that 2 + 2 is 4. Although specific transfer has been demonstrated in many experiments, it offers a somewhat circular view of teaching for transfer: The only way to help students be able to solve new problems is to teach them how to solve them in advance. General transfer means that although no elements are identical, the general experience of knowing A is somehow related to B; that is, learning A somehow improves one's mind so that taking on a new task such as B is affected. For example, some scholars have claimed that learning a foreign language such as Latin may instill mental discipline that helps you solve logic

TABLE 1–10 Three views of transfer

View of Transfer	Definition	Example	Instructional Implication
Specific transfer	Specific transfer of specific behaviors	Thorndike's theory of transfer by identical elements	Teach specific behaviors by drill and practice
General transfer	General transfer of general skills	Doctrine of formal discipline	Improve the mind by teaching Latin
Mixed transfer	Specific transfer of general principles or strategies	Katona's learning by understanding	Teach principles and strategies to explain solution behavior

problems—a claim we investigate in the next section. Unfortunately, researchers have not been able to produce much evidence for general transfer, so the implications for teaching for transfer are disappointing: It may not be possible to provide learning experiences that improve the mind in general. Finally, mixed transfer refers to specific transfer of a general principle or strategy; it occurs when a general principle or strategy used in A is also used in B. For example, learning the general strategy of how to critique psychology experiments in a course on social psychology may help you critique experiments in a course on educational psychology even though none of the experiments are the same. In this book, my primary focus is on mixed transfer, that is, helping students learn general principles or strategies that are specifically relevant to important academic tasks.

HISTORICAL OVERVIEW OF TEACHING FOR TRANSFER

Teaching for transfer is a classic goal of education but the history of such efforts is somewhat disappointing. The 20th century is littered with failed attempts to teach for transfer, yielding an "elusive search for teachable aspects of problem solving" (Mayer, 1987b, p. 327). As an example, consider the well-documented case of Latin schools, which was the first to be tested in educational psychology.

When the curtain rose on the 20th century, the dominant view of transfer was the doctrine of formal discipline—the idea that certain school subjects (such as Latin and geometry) improve learners' minds. In short, the doctrine of formal discipline was a theory of general transfer. Proponents claimed, for example, that learning Latin promoted proper habits of mind, including mental discipline and orderly thinking. According to this view, these general skills would transfer to all other academic tasks, even those completely unrelated to Latin. Rippa (1980) shows that in the 18th and 19th centuries, the curriculum of the Boston Latin School—the oldest in the United States—included being able to read, write, and speak Latin, as well as have some knowledge of Greek and geometry.

E. L. Thorndike is widely recognized as the first educational psychologist, and in the early 1900s he set his sights on testing the doctrine of formal discipline in scientific experiments (Mayer, 2003). He and his colleagues were the first to test for any evidence of general transfer in which learning one thing (e.g., Latin) would help students perform other tasks that had no elements in common (Thorndike, 1906; Thorndike & Woodworth, 1901). For example, in well-controlled laboratory studies, learning to perform one kind of task (such as estimating the length of lines 0.5 to 1.5 inches long) did not strongly affect performance on other tasks (such as estimating the length of lines 6 to 12 inches long). In classroom studies, students who took Latin did not perform better on tasks in new school subjects than did students who took more mundane classes. In an exhaustive series of studies, Thorndike found that learning to perform one cognitive task resulted in improvements on a different task, only to the extent that the two tasks shared many common elements.

Thorndike rejected the doctrine of formal discipline (with its emphasis on general transfer) and replaced it with his theory of transfer by identical elements (with its emphasis on specific transfer). According to Thorndike (1906): "One mental function or activity improves others in so far as and because they are in part identical with it, because it contains elements in common to them" (p. 243). For example, "knowledge of Latin gives increased ability to learn French because many of the facts learned in the one case are needed in the other" (p. 243). In rejecting the concept of general transfer, Thorndike offered a conception of the mind as a collection of domain-specific skills: "the mind is a host of highly particularized and independent abilities" (p. 39). The idea that learning and cognition are domain specific is still an important theme in cognitive science today (Mayer, 1999).

The results of Thorndike's research helped demolish the doctrine of formal discipline and the conception of general transfer on which it is based. Educators could no longer find scientific justification for teaching general skills such as mental discipline that were supposed to transfer to new tasks. Consistent with Thorndike's monumental research on transfer, the search for teachable aspects of general transfer has not been very successful.

Is the only alternative, then, for educators bent on teaching for transfer to accept a theory of specific transfer, such as Thorndike's theory of transfer by identical elements? If so, the only way to teach for transfer is to know in advance every problem the student would encounter and to teach the skills needed to solve those problems. In short, if all transfer is specific, then preparing students for completely novel problems is impossible. If this is true, then I can stop writing this book now, because my goal is to examine instructional methods that prepare students to solve problems they have never seen before.

There is an important alternative to theories of general transfer, which have been largely discredited, and to theories of specific transfer, which really don't allow for much problem-solving transfer. That alternative is what I have called specific transfer of general principles or strategies. According to this theory of mixed transfer, it is possible to learn certain general principles or strategies that are specifically applicable to new tasks.

Consider the following test of a mixed theory of transfer. Young boys are taught to shoot darts at an underwater target that is submerged 12 inches. When they are tested later on targets that are submerged only 4 inches, they make many errors. This result, you might say, is consistent with a theory of specific transfer because the boys seem to have learned behaviors that are appropriate only for the situation they learned about. However, suppose that for some of the boys, we provide brief instruction in the theory of refraction so they can understand how water level affects the apparent location of the target. In this case, practice with the 12-inch-deep target transferred to learning how to hit the 4-inch-deep target. Apparently, the boys learned a general strategy that applied to both situations. When Judd found these results in 1908, he offered an important compromise between theories of general transfer and theories of specific transfer.

The Gestalt psychologists (Katona, 1940; Wertheimer, 1959) compared two methods of teaching: learning by memorizing (which is based on a theory of specific transfer of specific behaviors) and learning by understanding (which is based on a theory of specific transfer of general principles). For example, consider a card problem in which you begin with a deck of eight cards, half red and half black:

> I take the top card and place it on the table. It is a red card. Then I take the next card and put it at the bottom of the deck without determining what it is. I place the third card on the table. It is a black card. The following card I place undetermined below the others; while the next card, which is red, I put on the table. The procedure of alternatively placing one card on the table and one at the bottom of deck was continued until all the cards of the deck were placed on the table; the cards appeared in this order: red, black, red, black, red, black, red, black. Then said the experimenter, "It is a nice trick, I suppose you would like to learn how to do it. I will teach you." (Katona, 1940, pp. 34–35)

Figure 1–6 shows two methods for teaching students how to solve this problem—learning by memorizing and learning by understanding. In learning by memorizing

FIGURE 1–6 Two instructional methods for the card trick problem: learning by memorizing and learning by understanding

LEARNING BY MEMORIZING

To achieve this goal, you must take in your hand first, two red cards; then, one black card; then, two red cards; and last, three black cards. [The experimenter writes the sequence on the board, repeats it aloud three times, and asks the student to repeat it until the student recites it twice without error.]

LEARNING BY UNDERSTANDING

? ? ? ? ? ? ? ?	. . . We put eight question marks on the blackboard. The first question mark represents the first card, the second question mark represents the second card, and so forth . . .
R ? B ? R ? B ?	The first card should be a red card. The second card should be placed below the others; since we do not know what it is, it is represented by a question mark. The third card must be a black card, while the fourth is unknown (a question mark), and so forth. The four cards that are designated by letters on the blackboard are supposed to be on the table. The four cards designated by question marks are still in my hand . . .
R ? B ?	The next card (that is, the first of the remaining question marks) must therefore be a red card. The following card, represented by the following question mark, has to be placed below the others and remains a question mark. Then, follows a black card and lastly a question mark.
R ?	Two question marks remain. . . . The first one must be a red card, while the next one remains a question mark.
B	This one being the last card, following a red card, must be black.
R R B R R B B B	Now we are ready to add up our findings: red, red, black, red, red, black, black, black.

Source: Adapted from Organizing and Memorizing, by G. Katona. Copyright © 1940 Columbia University Press. Reprinted with permission of the publisher.

students memorize a chain of behaviors that generates the answer. In learning by understanding, students learn a general principle or strategy that can apply to a wide variety of card problems.

On a retention test, in which students are asked to solve the same problem, both groups perform about the same—42% percent correct for the memorizing group and 44% for the understanding group. What happens on a transfer test in which students are asked to solve a new problem (same description except you put two cards on the bottom of the deck after each card you place on the table)? According to a theory of specific transfer (such as Thorndike's identical elements), both groups should perform poorly, but according to a theory of specific transfer of general principles or strategies (as suggested by Judd), the understanding group should perform better. The results show that the memorizing group performs poorly (8% correct) but the understanding group performs quite well (40% correct). Katona (1940) concludes that "learning by memorizing is a different process from learning by understanding" (p. 53). In learning by understanding, students discover a generalizable principle or strategy that makes sense to them and can be applied in a variety of problems that depend on the same principle or strategy. In this classic example lies the essence of what it means to teach for transfer.

In this book, I examine the research base concerning the effectiveness of each of instructional methods intended to promote meaningful learning.

What Is the Promise of Educational Psychology?

From today's vantage point—200 years after Itard's valiant efforts to teach Victor using learner-centered methods and 100 years after the beginnings of the scientific discipline of educational psychology—the future of educational psychology looks promising once again. Although education and psychology experienced a rocky relationship in the past, today's educational psychology holds great potential for improving educational practice and advancing psychological theory. In this section, we explore how educational psychology can contribute to evidence-based practice and improve how students learn school subjects.

EVIDENCE-BASED PRACTICE

Educational practice should be guided by research-based principles rather than unsubstantiated claims, opinions, and fads. This idea is called *evidence-based practice*, and is the basis for this book. In evidence-based practice, educational decisions are informed by an understanding of how students learn and of relevant research evidence on how to foster learning. What is the best way to teach students how to read, how to write, or to solve math problems? In taking an evidence-based approach, we ask what is known about how people learn to read, to write, or to solve math problems and what is known about how to help foster the learning process. A recent review commissioned by the National Research Council summarized the rationale for evidence-based practice as follows (Shavelson & Towne, 2002): "No one would think of getting to the Moon or wiping out a disease without research. Likewise, one cannot expect reform efforts in education to have significant effects without research-based knowledge to guide them" (p. 1).

What is the alternative to evidence-based practice? Shavelson and Towne (2002) note that "decisions about education are sometimes instituted with no scientific basis at all, but rather are derived directly from ideology or deeply held beliefs" (p. 17). Similarly, Mayer (2005e) has argued that "a significant obstacle to educational reform occurs when reformers base educational practice on doctrine rather than evidence-based theory" (p. 68). For example, some educational reformers may believe that learning in groups is a good idea, so students are broken down into groups of four and are responsible for helping each other learn. Others may believe that students should be free to explore without direct instruction from the teacher, so classrooms are full of hands-on explorations in which students choose their own problems to work on. There is nothing wrong with any of those proposals unless they are implemented without any supporting evidence. They all can be tested; in taking an evidence-based approach, the goal is to conduct research on student learning.

What is scientifically-based research? Scientific research has four central characteristics: (a) testable predictions—you begin with testable predictions that are derived from a clear theory; (b) appropriate methods—you use appropriate research methods to glean relevant evidence; (c) logical conclusions—you derive conclusions based on the evidence; and (d) continued scrutiny—you conduct additional studies and disclose your findings for critique. As you can see, evidence is at the heart of scientific research: Predictions must be stated in terms of expected empirical evidence, research methods must be capable of generating relevant evidence, evidence must be used for deriving conclusions, and evidence must be held up to scrutiny by others. Shavelson and Towne (2002) have shown that effective educational research should "pose significant questions that can be investigated empirically" and "link research to relevant theory" (i.e., corresponding to testable predictions), "use methods that permit direct investigation of the question" (i.e., corresponding to appropriate methods), "provide coherent, explicit chain of reasoning" (i.e., corresponding to logical conclusions), and "replicate and generalize across studies" and "disclose research to encourage professional scrutiny and critique" (i.e., corresponding to continued scrutiny) (pp. 3–6). These characteristics and their supporting principles are listed in Table 1–11. In order for educational practice to be evidence based, the evidence should come from scientifically valid research.

WHAT GOOD IS EDUCATIONAL PSYCHOLOGY?

What is the promise of educational psychology; that is, how can educational psychology contribute to education and psychology? The theme of this book is that the two most promising contributions of educational psychology are:

Psychologies of subject matter: a focus on developing, learning, teaching, and thinking within the context of specific subject areas.

Cognitive process instruction: a focus on fostering cognitive processing that leads to meaningful learning.

Thus, this book represents a sort of progress report covering recent advances in the cognitive psychology of subject matter and the cognitive psychology of instructional methods.

The first promising contribution of educational psychology is a focus on psychologies of subject matter. In contrast to traditional experimental psychology's focus on general

TABLE 1–11

Four characteristics of scientific research in education

Characteristic	Principles
Testable predictions	Pose significant questions that can be investigated empirically. Link research to relevant theory.
Appropriate methods	Use methods that permit direct investigations of the question.
Logical conclusions	Provide coherent, explicit chain of reasoning.
Continued scrutiny	Replicate and generalize across studies. Disclose research to encourage professional scrutiny and critique.

Source: Principles are based on Shavelson and Towne (2002).