As the first editor of the *Journal of Educational Psychology* in 1910, Thorndike envisioned that educational psychologists would apply the exact methods of science to the problems of education. Thus began this 100-year-old vision that the "proper application of psychological findings might lead the way to better instruction in all schools" (Woodring, 1958, p. 6).

Yet, even during the optimism of the early 1900s, educational psychologists recognized that psychology was not likely to be able to satisfy the needs of educators. In his famous lectures on psychology for teachers, which he later published as *Talks to Teachers*, the great American psychologist William James (1899/1958) admitted his doubts as follows:

> The desire of the schoolteachers for a completer professional training, and their aspiration toward the professional spirit in their work, have led more and more to turn to us for light on fundamental principles. . . . You look to me . . . for information concerning the mind's operation, which may enable you to labor more easily and effectively in the several classrooms over which you preside. . . . Psychology ought certainly to give the teacher radical help. And yet I confess that, acquainted as I am with the height of your expectations, I feel a little anxious lest, at the end of these simple talks of mine, not a few of you may experience some disappointment at the net results. (p. 22)

James acknowledged two obstacles blocking the application of psychology to education. First, James (1899/1958) correctly observed that the psychology of the late 1800s lacked a sufficient database, and that much work needed to be done to test psychological theories. Second, James warned that psychological research results and theories would not necessarily translate directly into prescriptions for classroom practice: "You make a great, a very great mistake, if you think that psychology, being a science of the mind's laws, is something from which you can deduce definite programmes and schemes and methods of instruction for immediate classroom use" (p. 23).

PHASE 2: DEAD-END STREET FOR PSYCHOLOGY IN EDUCATION

Despite the aspirations of early educational psychologists, the discipline of educational psychology was in serious trouble by the mid-1900s. Educators and psychologists became pessimistic concerning whether educational psychology would be able to assume its role as the guiding science of education. Psychologists busied themselves by studying the learning of laboratory animals, such as rats running in mazes, or human learning of senseless material in rigid laboratory settings, such as memorizing lists of nonsense syllables—issues that seemed far removed from the world of education. Educators focused on practical issues, such as whether one method was better than another for teaching a given skill, while failing to base educational decisions on a coherent theory of how students learn.

Grinder (1989) identified three reasons for the decline of educational psychology in the mid-1900s:

Withdrawal: Educational psychologists lost interest in contributing to educational policy.
Fractionation: Educational psychologists failed to achieve a coherent theoretical perspective.
Irrelevance: Educational psychologists focused on research issues far removed from the problems of schooling.

In short, during this dead-end phase, psychology and education became disconnected.

PHASE 3: TWO-WAY STREET BETWEEN PSYCHOLOGY AND EDUCATION

Something happened in the late 1950s and early 1960s that brought a new phase of optimism to educational psychology. That something was the "transition from behavioral to cognitive psychology" (DiVesta, 1989, p. 39), or what Scandura et al. (1981) called the "shift from S-R [stimulus-response] to information processing" theories (p. 367). The cognitive revolution in educational psychology highlighted "the learner as an active participant in the learning process" (DiVesta, 1989, p. 54). It encouraged research that examines how real students learn in real classroom settings, with a particular focus on the individual learning strategies that students use when faced with learning school material such as reading or writing or arithmetic. This view allowed the discipline of educational psychology to overcome the withdrawal, fractionation, and irrelevance that previously plagued it.

In a historical review, Mayer (1992a) asked: "Can educational psychology regain its position as the guiding science of education?" (p. 406). In many ways, this book provides the latest installment in educational psychology's quest to become the place where psychology and education meet. During the first part of the 20th century, educational psychology failed largely because it lacked the research tools and database necessary to improve education. During the middle part of the century, educational psychology failed because of its unwillingness to build theories that were relevant to improving education. In the last part of this century, however, educational psychology acquired both research tools and theories relevant to improving education. After 100 years, there again is cause for optimism reviving the vision of educational practice based on scientific theory as well as psychological theory based on real human learning.

The road between psychology and education has become a two-way street. The road runs from education to psychology: By providing the research agenda, education challenges psychology to develop theories about real people in real situations rather than theories that are limited to how people learn contrived tasks in artificial laboratory settings. The road runs from psychology to education: By developing useful theories of human learning and cognition and development, psychology provides the basis for making informed decisions about educational practice. In summary, "educational psychology—rather than being the place solely to apply psychological theories that have been developed elsewhere—is an exciting venue for shaping and testing the dominant psychological theories of the day" (Mayer, 1993a, p. 553).

Three Metaphors of Learning

If I asked you to complete the following sentence, how would you respond?

Learning is like:

_____ strengthening a connection (i.e., adding new behaviors to your repertoire).
_____ adding files to a file cabinet (i.e., adding new facts and skills to your knowledge base).
_____ building a model (i.e., understanding how to fit pieces of information together).

If you chose the first answer, you seem to view *learning as response strengthening*—the idea that learning involves adding new responses to an ever-growing collection. If you chose the second answer, you view *learning as knowledge acquisition*—the idea that learning involves

TABLE 1–2 Three metaphors of learning

Learning is	The Learner is a	The Teacher is a	Typical Instructional Methods
Response strengthening	Passive recipient of rewards and punishments	Dispenser of rewards and punishments	Drill and practice on basic skills
Knowledge acquisition	Information processor	Dispenser of information	Textbooks, workbooks, and lectures
Knowledge construction	Sense maker	Guide for understanding academic tasks	Discussion, guided discovery, and supervised participation in meaningful tasks

transferring knowledge from the teacher's head to the student's head. If you chose the third answer, you view *learning as knowledge construction*—the idea that students actively create their own learning by trying to make sense out of their experiences.

These three views of learning represent three persistent metaphors developed over the history of psychology in education: metaphors invented by psychologists and applied by educators. Examining your personal metaphor of learning is worthwhile because educational practice can be influenced by the educator's underlying metaphor of learning. Table 1–2 summarizes three common metaphors for learning: learning as response strengthening, learning as knowledge acquisition, and learning as knowledge construction.

LEARNING AS RESPONSE STRENGTHENING

The first metaphor to gain broad acceptance in psychology is learning as response strengthening, which evolved throughout the first half of the 20th century and was based largely on research on laboratory animals. According to this view, learning is a mechanical process in which successful responses to a given situation are automatically strengthened and unsuccessful responses to the situation are weakened. In this way, learning is like strengthening or weakening the association between a stimulus (S) and a response (R). Thus, the term "response strengthening" includes the idea of both strengthening and weakening of responses, or more properly, of stimulus-response (S-R) associations. For example, in reading, a to-be-strengthened S-R association may be between the printed word "cat" and its corresponding sound; in writing between the spoken word "cat" and its corresponding spelling "c-a-t"; and in arithmetic, between "4 + 4 =" and "8." According to this metaphor, the learner becomes a passive recipient of feedback who is completely shaped by rewards and punishments in the environment, and the teacher becomes a feedback dispenser who delivers rewards and punishments.

The learning-as-response-strengthening view suggests educational practice in which the teacher creates situations that require short responses, the learner gives a response, and the teacher provides the appropriate reward or punishment. For example, the teacher may ask, "What is 750 divided by 5?" If the student responds with the correct answer ("150") the teacher says, "Right, good job." If the student responds with an incorrect answer ("250"), the teacher may say, "No, you need to review the worksheet." As you can see, drill and practice is a popular method of instruction that is consistent with the learning-as-response-strengthening metaphor. When they accept the learning-as-response-strengthening metaphor, educators emphasize teaching of basic skills in reading, writing, and arithmetic.

LEARNING AS KNOWLEDGE ACQUISITION

The second metaphor, learning as knowledge acquisition, developed during the 1960s and 1970s as research shifted from studying animal learning in laboratory settings to studying human learning in laboratory settings. According to this view, learning occurs when information is transferred from a more knowledgeable person (such as a teacher) to a less knowledgeable person (such as a student). In this way, learning is like filling a void, that is, like pouring information into a student's memory. Within this metaphor, the learner becomes a processor of information and the teacher becomes a dispenser of information. Information is a commodity the teacher gives to the student.

The learning-as-knowledge-acquisition view suggests educational practice in which the teacher presents new information for the student to learn. For example, the teacher may ask students to read a section in their science textbooks on how electricity flows in a circuit, and then test them on the material. As you can see, the goal of instruction is to increase the amount of knowledge in the learner's memory, so textbooks and lectures offer popular methods of instruction. When educators call for covering material in the curriculum, they are working under a learning-as-knowledge-acquisition metaphor.

LEARNING AS KNOWLEDGE CONSTRUCTION

The third metaphor is learning as knowledge construction, the idea that learners actively build their own mental representations as they attempt to make sense out of their experiences. This view grew out of research on human learning in realistic settings conducted since the 1970s and 1980s. Learning occurs when people select relevant information, organize it into a coherent structure, and interpret it through what they already know. Resnick (1989) expresses this view as follows: "Learning occurs not by recording information but by interpreting it" (p. 2). According to this view, the learner is a sense maker and the teacher is a guide who assists students as they seek to understand how to perform academic tasks. The focus is on the learner and on helping the learner build cognitive strategies for academic learning tasks.

The educational practices suggested by the learning-as-knowledge-construction view include group discussions and supervised participation in meaningful academic tasks. For example, in learning how to write, students may discuss how they plan what to say and the teacher may offer suggestions along the way. Instead of emphasizing the learning products—such as how much is learned—this view emphasizes the learning processes, such as strategies for how to learn and understand. When educators take a "learner-centered" approach, they are consistent with the learning-as-knowledge-construction metaphor.

There is merit in each of these metaphors and in the instructional methods they suggest (Mayer, 1996a). However, in this book, I rely most heavily on the learning-as-knowledge-construction metaphor because I think it offers the most potential benefit for improving education, that is, it seems most likely to promote the promise of educational psychology to emphasizing knowledge construction. I do not mean to diminish the value of learning basic skills, such as facts and procedures. However, according to the knowledge-construction metaphor, basic skills should be learned in the context of larger academic tasks rather than in isolation. For example, learning Ohm's law could occur as part of a project involving the design of a real electrical circuit rather than memorizing the formula in isolation.

How People Learn: A Cognitive Theory of Meaningful Learning

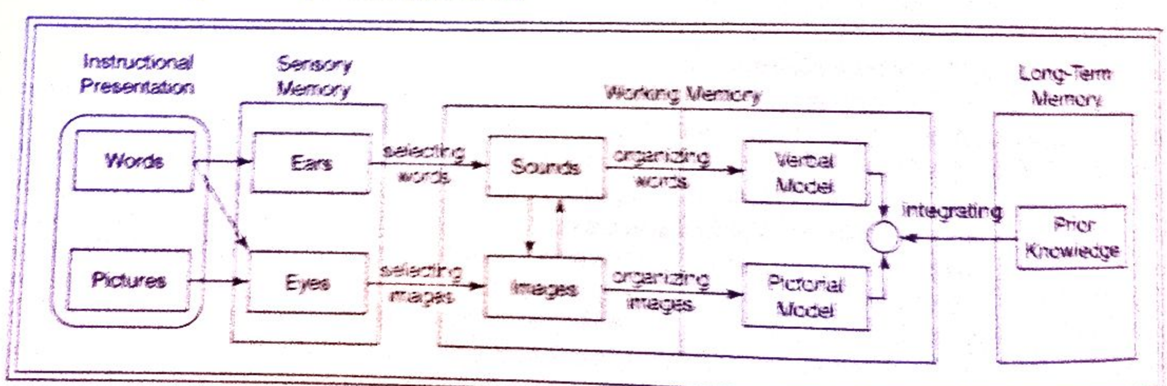
This book is concerned mainly with influencing the intellectual growth of the learner. More specifically, this book focuses on understanding how instructional manipulations affect changes in the learner's knowledge, including changes in learning strategies and the structure of memory. As you can see, the learner's construction of knowledge is at the center of the educational process. Helping change the learner's knowledge—manifested in changes in academic, motor, social, and personal behavior—is what education is all about.

If knowledge construction is at the center of educational psychology, then the learner's learning system is where the action is! Figure 1–3 describes the basic architecture of the learning system. As you can see, the learning process begins with an instructional presentation consisting of words (such as printed text or spoken text) and pictures (such as illustrations or animations). In this section I explain the three principles underlying this model, and I describe the three memory stores, the three cognitive processes, and five kinds of knowledge.

THREE PRINCIPLES OF LEARNING

How do people learn? To help answer this question I draw on three basic principles from research on cognitive science—*the dual channels principle, the limited capacity principle*, and *the active learning principle*. The dual channels principle is the idea that people have separate channels for processing visual and verbal material (Baddeley, 1999; Paivio, 1986).

FIGURE 1–3 Cognitive theory of meaningful learning



Adapted from Mayer (2001b).

TABLE 1–3 Three principles of learning from cognitive science	Principle	Description	Instructional Implications
	Dual channels	Learners possess separate channels for processing verbal pictorial information.	If needed, help the learner coordinate verbal and pictorial representations of the same concept.
	Limited capacity	Learners are limited in the amount of information they can process in each channel at one time.	Do not overload the learner's learning system by presenting too much material at one time.
	Active processing	Learners engage in active learning by paying attention to relevant information, organizing it into coherent mental representations, and integrating representations with other knowledge.	Encourage the learner to engage in making sense of the material.

Principles are based on Baddeley (1999), Mayer (2001a), Paivio (1986), Sweller (1999), and Wittrock (1989).

In Figure 1–3, the top row represents the verbal channel and the bottom row represents the visual channel. The limited capacity principle is that people are able to actively process only a limited amount of material in a channel at one time (Baddeley, 1999; Sweller, 1999). In Figure 1–3, the central portion of the system is labeled "Working Memory" to indicate that processing capacity is highly limited. The active learning principle is that meaningful learning occurs when learners engage in appropriate cognitive processing during learning, such as attending to relevant information, mentally organizing relevant information into a coherent structure, and mentally integrating representations with each other and with prior knowledge retrieved from long-term memory (Mayer, 2001b, 2005a; Wittrock, 1989). In Figure 1–3, the arrows labeled "selecting," "organizing," and "integrating" represent these cognitive processes. These three principles are summarized in Table 1–3.

THREE MEMORY STORES IN MEANINGFUL LEARNING

As you can see in Figure 1–3, there are three main components indicated by large rectangles—sensory memory, working memory, and long-term memory.

Sensory memory: Incoming information is accepted by the sense receptors and is held briefly in a sensory memory store. According to the classic model, the capacity of sensory memory is unlimited, the mode of representation is sensory, the duration is brief (e.g., one half second for visual information), and loss occurs due to time decay.

Working memory: If you pay attention to the incoming information before it decays, you may be able to transfer some of that information to working memory (WM). You can think of working memory as that part of memory corresponding to your active consciousness or awareness. According to the classic model, the capacity of working

[illegible]	Memory Store	Description	Instructional Implications
[illegible]	Sensory memory	[illegible]	[illegible]
	Working memory	[illegible]	[illegible]
	Long-term memory	[illegible]	[illegible]

[illegible]

Long-term memory: [illegible]

[illegible] Table 1-4.

THREE COGNITIVE PROCESSES IN MEANINGFUL LEARNING

[illegible]

Selecting [illegible]

Organizing [illegible]

TABLE 1–5 Three cognitive processes used in meaningful learning

Cognitive Process	Description	Resulting Knowledge	Instructional Implications
Selecting	Paying attention to relevant elements in the presented material	Sounds and visual images	Learners may need guidance in how to attend
Organizing	Constructing internal connections among incoming elements	Verbal model and pictorial model	Learners may need guidance in how to organize
Integrating	Constructing external connections among representations and prior knowledge	Integrated model	Learners may need guidance in how to integrate

Integrating: involves constructing external connections between the newly organized knowledge in working memory and existing relevant knowledge that the learner retrieves from long-term memory, as indicated by the arrow "integrating." This process involves "connecting the organized information to other familiar knowledge structures already in memory" (Mayer, 1984, p. 33). Sternberg (1985) referred to integrating as *selective comparison*, and described it as "relating newly acquired or retrieved knowledge . . . to old knowledge so as to form an externally connected whole" (p. 107). Integrating also includes building connections between two pieces of newly organized knowledge such as a verbal representation and a pictorial representation of the same concept.

As you can see, the learner uses selecting, organizing, and integrating processes to construct new knowledge in working memory. Knowledge constructed in working memory is transferred to long-term memory for permanent storage, via the process of *encoding*, which is represented by the arrow from working memory to long-term memory. The three learning processes are summarized in Table 1–5.

FIVE KINDS OF KNOWLEDGE

If learning is knowledge construction, it is important to understand the kinds of knowledge that people construct. Educational and cognitive psychologists generally distinguish among several different kinds of knowledge, including facts, concepts, procedures, strategies, and beliefs (Anderson et al., 2001; Kilpatrick, Swafford, & Findell, 2001; Mayer, 2001b):

Facts: Facts are the elements of a person's factual knowledge (or semantic knowledge) about the world. Examples include being able to answer the questions, "What is the capital of California?" or "How many sides does a square have?"

Concepts: Concepts refer to a person's representation of categories, schemas, principles, and models of a domain. Examples of conceptual knowledge (i.e., principles and models) include being able to answer questions such as, "What is the difference between the units column and the tens column in two-column addition problems such as 39 + 45 = ________?" An example of schematic knowledge (i.e., categories and schemas) is being able to distinguish between word problems that require the use of a time-rate-distance formula and those requiring a formula for computing mixtures.

Procedures: A procedure (also called procedural knowledge) is an algorithm, or list of steps, that can be used in a specific situation. An example is being able to use the procedure for long division to solve the problem $234234 \div 13 =$ ______. Another example is being able to change a word to plural form using the rule "Add s."

Strategies: A strategy (also called strategic knowledge) is a general approach for how to learn or remember or solve problems, including the self-monitoring of progress in the use of the strategy. Examples include being able to design and monitor a plan for how to compose an essay, or being able to decide on a technique for how to memorize a list of definitions. Metacognitive strategies are strategies for assessing one's capabilities and progress in a learning situation.

Beliefs: A belief is a learner's thoughts about his or her learning characteristics, how learning works, and the nature of a particular domain. For example, a student may believe that mathematics is really not understandable by 99% of the people or that if you make a mistake on a problem that means you can't solve it without help. Self-efficacy beliefs refer to beliefs about one's capacity to perform a task, such as thinking, "I am not able to learn statistics." Personal epistemologies refer to people's beliefs about knowledge and learning, such as, "There is one correct way to solve a problem and the teacher knows it."

These five kinds of knowledge are summarized in Table 1–6. Performing most academic tasks, such as solving a word problem or writing an essay, draws on many types of knowledge that must be interwoven for success on the task. In subsequent chapters, we explore how

TABLE 1–6

Five types of knowledge

Type	Description	Examples
Facts	Elements of a learner's factual knowledge about the world	Sacramento is the capital of California. A square has four sides.
Concepts	Categories and schemas (schematic knowledge) and principles and models (conceptual knowledge)	"How long will it take Sarah to drive 240 miles if she travels at a rate of 60 miles per hour?" is a time-rate-distance problem. In the number 567, the 6 refers to the number of tens.
Procedures	A step-by-step process or algorithm	Computing an answer for 252 divided by 12. Making the word "dog" plural by adding "s."
Strategies	A general method for learning, remembering, or problem solving	Breaking a word problem into smaller parts.
Beliefs	Thoughts about one's learning characteristics, how learning works, or the nature of a subject area	Thinking "I am not able to learn statistics."

each kind of knowledge is related to school tasks. Other kinds of knowledge include affective, motoric, personal, or social knowledge. However, this book focuses mainly on the kinds of knowledge noted in the preceding list because they represent the areas in which most of the educational research has been carried out.

How to Help People Learn: A Cognitive Model of Instruction

SIX FACTORS IN THE TEACHING–LEARNING PROCESS

Table 1–7 summarizes a cognitive model of meaningful instruction that includes six factors that might be involved in the teaching–learning process. The factors are as follows:

Instructional manipulations: the sequence of environmental (i.e., external) events including the organization and content of instructional materials and the behaviors of the teacher. The instructional manipulations include both what is taught and how it is taught, and depend on the characteristics of the teacher and on the curriculum.

Learner characteristics: the learner's existing knowledge, including facts, procedures, and strategies that may be required in the learning situation, and the nature of the learner's memory system, including capacity and mode of representation in memory.

Learning context: the social and cultural context of learning, including the social structure of the classroom and school.

Learning processes: the learner's internal cognitive processes during learning, such as how the learner selects, organizes, and integrates new information with existing knowledge.

Learning outcome: the cognitive changes in the learner's knowledge or memory system, including the newly acquired facts, procedures, and strategies.

Outcome performance: the learner's performance (i.e., behavior) on tests, such as retention or transfer to new learning tasks.

TABLE 1–7

Examples of factors in the teaching–learning process

Instructional Manipulations	Learning Context	Learner Characteristics	Learning Processes	Learning Outcome	Outcome Performance
Repeating a lesson	Social and cultural context	Existing knowledge	Selecting information	Rote learning	Retention
					Transfer
Providing examples		Existing information-processing strategies	Organizing information	Meaningful learning	
Asking questions			Integrating information		

Adapted from Mayer (1984).