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Logan Fiorella and Richard E. Mayer
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1

Introduction to Learning as a Generative Activity

SUMMARY

This book is based on the idea that meaningful learning is a generative activity in which the learner actively seeks to make sense of the presented material. The study of generative learning has implications for the science of learning, the science of assessment, and the science of instruction. Concerning the science of learning, generative learning takes place when the learner engages in appropriate cognitive processing during learning, including attending to the relevant information (i.e., selecting), mentally organizing incoming information into a coherent cognitive structure (i.e., organizing), and integrating the cognitive structures with each other and with relevant prior knowledge activated from long-term memory (i.e., integrating). Concerning the science of assessment, generative learning is demonstrated when students who learn with generative learning strategies or generative instructional methods perform better on transfer tests than students who learn from standard instruction. Concerning the science of instruction, generative learning can be promoted through *instructional methods* aimed at designing instruction that primes appropriate cognitive processing during learning or through *learning strategies* aimed at teaching students how and when to engage in activities that require appropriate cognitive processing during learning. This book focuses on eight generative learning strategies that have been shown to improve student learning: summarizing, mapping, drawing, imagining, self-testing, self-explaining, teaching, and enacting. The concept of generative learning has roots in the work of Wittrock and others, continues as a dominant view of learning today, and shows promise of further development in the future.

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CHAPTER OUTLINE

1. Getting Started
2. What Is Generative Learning?
3. Implications of Generative Learning for the Science of Learning
4. Implications of Generative Theory for the Science of Assessment
5. Implications of Generative Theory for the Science of Instruction
6. What Is the Past and Future of Generative Learning?

GETTING STARTED

What Can You Do?

Suppose you sit down to read a book chapter, you attend a PowerPoint lecture, or you view an online multimedia presentation. You are proficient at reading and listening, so you can easily understand all the words. Yet, when you are finished with the lesson, you are not able to apply what you have learned to new situations or to use the material to solve problems. What could you have done to help you understand the material rather than simply to process every word?

This book is concerned with exploring what the research evidence has to say about answering this seemingly simple question. Our proposed solution is that you could engage in *generative learning strategies* during learning – activities that are intended to prime appropriate cognitive processing during learning (such as paying attention to the relevant information, mentally organizing it, and integrating it with your relevant prior knowledge).

For example, you could try to summarize the material in your own words (perhaps by taking summary notes), you could create a spatial summary of the material as a matrix or network, you could make a drawing that depicts the main ideas in the text, or you could just imagine a drawing. These are all ways of translating the lesson into another form of representation.

Alternatively, you could give yourself a practice test on the material (such as trying to answer some questions), you could explain the material aloud to yourself during learning, you could explain the material to someone else, or you could use concrete objects to act out the material in the lesson. These are all ways of elaborating on the material.

Exploring each of these eight kinds of generative learning strategies is the primary goal of this book.

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Try This

Let's begin with a brief assessment of your view of learning. Most people have an implicit theory of learning, because we all have spent so much time in school. Please place a check mark next to each item that corresponds with your conception of how learning works.

— Learning works by engaging in hands-on activity, so it is better for you to learn by doing rather than by being told.
— Learning works by building associations, so you should practice giving the right response over and over.
— Learning works by adding information to your memory, so you should work hard to find and memorize new material.
— Learning occurs when you try to make sense of material you encounter, so you should strive to relate new information with your prior knowledge.
— Learning is a social activity, so it is better for you to learn with others in a group than to learn alone.

If you checked the fourth item, your view of learning corresponds to the conception of generative learning proposed in this book – which simply shows you have the good common sense to agree with us. As you will see in this book, the learner's cognitive processing during learning is a major contributor to what is learned.

If you are like most people, you made some other check marks. The first item is appealing, but according to the generative learning view, it focuses too much on behavioral activity and not enough on cognitive activity. Doing things does not necessarily cause learning, but thinking about what you are doing does cause learning. Thus, the first item should be modified to say, "Learning works by engaging in appropriate cognitive activity during learning."

The second item also seems appealing and is consistent with the first theory of learning to emerge in psychology and education more than a century ago – which can be called *associative learning*. However, according to the generative learning view, learning by forming associations applies to a narrow band of learning situations – such as learning to give the right response for a given stimulus. Associative learning is not wrong, but it is just too limited. It does not deal with learning by understanding, which allows people to take what they have learned and apply it in new situations.

The third item may sound familiar because it seems consistent with some common educational practices such as asking students to attend hours of

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lectures or read hundreds of textbook pages. What is wrong with this item, however, is that humans do not work like computers. We do not simply take in what was presented and put it into our memory. Instead, we interpret it, we reorganize it, and we relate to what we already know, thereby changing what is presented from information (which is objective) into knowledge (which is personal).

Finally, the last item is consistent with an emerging vision of learning based on the idea that generative learning occurs best within group contexts – that is, when you can interact with others during the learning process. However, research on group learning tends to show that all group interactions are not equally helpful in promoting meaningful learning. Thus, generative learning theory – indicated by the fourth item – can be expanded to include social activities that promote appropriate cognitive processing during learning and to exclude social activities that do not. Overall, the point of this little exercise is to help you understand how the generative learning view is different from what might seem like some common-sense views of learning.

Turning Passive Learning Situations into Active Learning Situations

Suppose that you are about to read a textbook chapter on the history of the U.S. postal service, attend a PowerPoint lecture on how a virus causes a cold, or view an online narrated animation explaining how lightning storms develop. Each of these activities – reading a book, attending a lecture, or viewing an online presentation – seems like a passive experience destined to foster suboptimal learning.

You might be surprised to learn that there are effective techniques that can be used to turn such seemingly passive learning situations into active learning experiences that produce meaningful learning. This book presents eight ways to help people learn based on a generative theory of learning – the idea that meaningful learning occurs when people engage in generative processing during learning. In particular, each of the techniques seeks to encourage learners to relate the represented material to what they already know, or reorganize the presented material into a coherent structure, or distinguish what is important from what is not. In this chapter, we describe what we mean by generative learning; explain how generative learning contributes to the science of learning, the science of assessment, and the science of instruction; and end with a brief review of the history of scholarship on generative learning.

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WHAT IS GENERATIVE LEARNING?

Learning is a generative activity. This statement embodies a vision of learning in which learners actively try to make sense of the instructional material presented to them. They accomplish this goal by actively engaging in generative processing during learning, including paying attention to the relevant aspects of incoming material (which we call *selecting*), organizing it into a coherent cognitive structure in working memory (which we call *organizing*), and integrating cognitive structures with relevant prior knowledge activated from long-term memory (which we call *integrating*).

As you can see, the learner's cognitive processing plays a central role in generative learning. Learning is not simply a process of adding information to memory, as in a computer. Instead, learning depends both on what is presented and on the learner's cognitive processing during learning.

Similarly, the learner's prior knowledge plays a central role in generative learning. Prior knowledge includes schemas, categories, models, and principles that can help guide what the learner selects for further processing, how the learner organizes it, and how the learner links it with other structurally similar knowledge. Thus, learning depends both on what the instructor presents and what the learner brings to the learning situation. This is why two learners can be exposed to the same learning scenario – such as attending the same lecture or viewing the same online presentation – and come away with quite different learning outcomes.

As summarized in Table 1.1, not all forms of learning are *generative learning* – that is, learning by understanding, which results in meaningful learning outcomes. Another common form of learning is *rote learning* – that is, learning by memorizing, which results in rote learning outcomes. Finally, there is also *associative learning* – that is, learning by strengthening associations, which results in rapid responses to well-learned stimuli. Although there are other forms of learning, in this book, we focus on

TABLE 1.1. *Three kinds of learning situations*

Learning situation	What happens	What is enabled
Generative learning	Making sense of information	Solving new problems
Rote learning	Memorizing information	Remembering what was presented
Associative learning	Building associations	Giving a response for a stimulus

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generative learning. In particular, we focus on ways to promote generative learning because we are interested in helping students transfer what they have learned to new situations.

Our rationale for focusing on generative learning is that the twenty-first century needs problem solvers and sense makers (Pellegrino & Hilton, 2012). The need for rote learning and associative learning is somewhat reduced because we now have access to databases that can store vast amounts of information or give answers to simple questions. The world needs people who can select, interpret, and use information to solve new problems they have not encountered before. In short, today's focus on twenty-first-century skills such as creative problem solving, critical thinking, adaptability, complex communication, and constructing evidence-based arguments can be seen as a call for generative learning that helps people develop "transferable knowledge and skills" (Pellegrino & Hilton, 2012, p. 69).

IMPLICATIONS OF GENERATIVE LEARNING FOR THE SCIENCE OF LEARNING

The science of learning is the scientific study of how people learn (Mayer, 2011). This section examines the cognitive processes, memory stores, and knowledge representations involved in generative learning, as well as the motivational and metacognitive processes that support them.

Cognitive Processes in Generative Learning

How does learning work? The basic premise of generative learning theories is that learning occurs when learners apply appropriate cognitive processes to incoming information. Figure 1.1 summarizes the *SOI model of generative learning,* which focuses on three cognitive processes indicated by arrows – selecting, organizing, and integrating. As indicated by the arrow from *instruction* to *sensory memory,* instruction from the outside world enters your cognitive system through your eyes and ears (or other senses) and is briefly held in your sensory memory for a fraction of a second. If you pay attention to some of this fleeting information in sensory memory, you transfer the attended material to working memory for further processing (as indicated by the *selecting* arrow). In working memory, you can mentally reorganize the selected material into coherent mental representations (as indicated by the *organizing* arrow). You can also activate relevant prior knowledge from long-term memory and integrate it with incoming material in working memory (as indicated by the *integrating* arrow).

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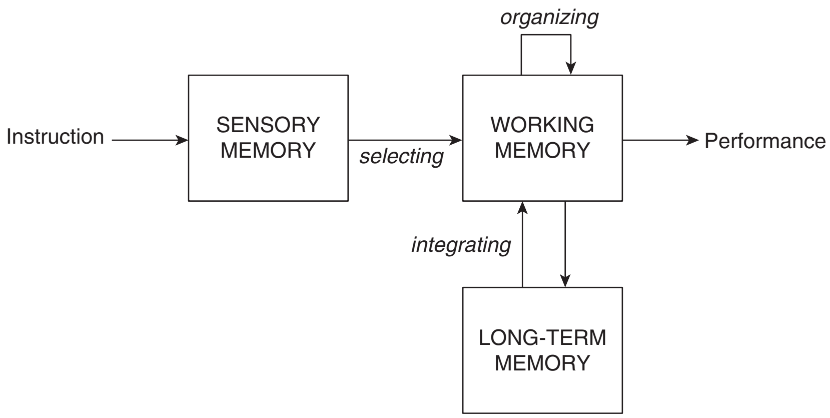

FIGURE 1.1. The SOI Model of Generative Learning.

TABLE 1.2. *Three cognitive processes in generative learning*

Cognitive process	Description	Arrow in SOI Model
Selecting	Attending to relevant material	Arrow from sensory memory to working memory
Organizing	Mentally organizing incoming material into a coherent cognitive structure	Arrow from working memory back to working memory
Integrating	Connecting cognitive structures with each other and with relevant material activated from long-term memory	Arrow from long-tem memory to working memory

The knowledge you build in working memory can be stored in long-term memory for future use (as indicated by the arrow from *working memory* to *long-term memory*) and can be used to solve problems you encounter in the outside world (as indicated by the arrow from *working memory* to *performance*).

An important instructional implication of the SOI model is that the instructor's job is not only to present information but also to make sure his or her students engage in appropriate processing during learning – including selecting, organizing, and integrating. Similarly, the learner's job is not to memorize the information exactly as it is presented but to engage in appropriate cognitive processing during learning. Table 1.2 summarizes the three cognitive processes in the SOI model of generative learning, which has been continuously adapted to the study of learning strategies over the past thirty

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TABLE 1.3. *Three memory stores in generative learning*

Memory store	Description	Capacity	Duration
Sensory memory	Holds visual images and sounds of what was presented	High	Very short
Working memory	Allows pictures and words to be held and manipulated	Limited	Short
Long-term memory	Acts as permanent storehouse of knowledge	High	Long

years (Kiewra, 2005; Mayer, 1988, 1994, 1996, 2011; Peper & Mayer, 1986; Shrager & Mayer, 1989; Weinstein & Mayer, 1985).

Memory Stores in Generative Learning

The SOI model of generative learning shown in Figure 1.1 contains three memory stores, indicated by the boxes. *Sensory memory* holds sensory copies of the visual images you saw and the sounds you heard (and other input from other senses) for a fraction of a second, so it has high capacity for a very short duration. In *working memory*, pieces of information can be consciously held and manipulated, but the capacity of working memory is quite limited so you can actively process only a few pieces of information at any one time (and without active processing, information is lost within about twenty seconds). *Long-term memory* is your permanent storehouse of knowledge, so it has high capacity and long duration.

According to the SOI model shown in Figure 1.1, working memory is a sort of bottleneck in your cognitive system because it has limited processing capacity (i.e., only a few elements can be actively processed at one time), whereas sensory memory and long-term memory on either side of it each have large capacities. An important instructional implication of this bottleneck is that rapidly presenting a lot of information to a learner is likely to overload the learner's working memory and result in much of the information being lost. The three memory stores in the SOI model of generative learning are summarized in Table 1.3.

Knowledge Representations in Generative Learning

In addition to understanding the boxes and arrows in Figure 1.1, it is worthwhile to consider the kinds of external and internal representations involved in generative learning. For example, consider what happens when

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TABLE 1.4. *External and internal representations in generative learning*

Representation	Type	Location
Printed words, spoken words, graphics	External	Instruction
Visual images and sounds	Internal	Sensory memory
Spatial and verbal representations	Internal	Working memory
Knowledge	Internal	Long-term memory

you attend a narrated slideshow lecture. We begin with the instructional presentation involving *spoken words, printed words, and graphics*, which become *visual images and auditory sounds* in your sensory memory, *spatial and verbal representations* that can be manipulated in working memory, and *semantic knowledge* stored in long-term memory. The conversion of presented information (i.e., the external representation) into constructed knowledge (i.e., the internal representation) is what happens when learners engage in generative learning. Three important steps in the development of knowledge in working memory are to select the pieces of information for further processing, to build internal connections among them so they form a coherent representation, and to build external connections with other representations in a systematic way. Table 1.4 lists the progression of representations in generative learning.

Metacognition and Motivation in Generative Learning

Generative learning requires that learners apply appropriate cognitive processes during learning, but how do learners know which processes to apply and when to apply them? How do you know which information to select, what kind of organization to build, and which aspect of prior knowledge to activate? Monitoring and controlling your cognitive processes during a cognitive task (such as learning from a lecture or from a book) is called *metacognition*. Thus, an important task of generative learning theories is to understand the workings of metacognitive strategies – that is, strategies for monitoring and controlling cognitive processes.

Even if you are skilled in using the cognitive processes of selecting, organizing, and integrating, and even if you possess the metacognitive strategies for orchestrating them, you may still not engage in generative learning because you just don't want to. What causes people to initiate and maintain generative processing at a high level during learning? *Motivation* is defined a cognitive state that initiates, energizes, and maintains goal-directed behavior. In short, motivation drives the cognitive system, so it is crucial

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to incorporate motivational mechanisms into generative learning theory. In particular, the learning strategies suggested in this book are intended to motivate learners to engage in productive cognitive processing during learning.

We refer to metacognition and motivation as the *Mighty M's* because they power the SOI model of generative learning shown in Figure 1.1. Without the motivation to make sense of a lesson, generative learning would not be initiated. Without the metacognitive skills to control cognitive processing during learning, attempts at generative learning would not be effective.

IMPLICATIONS OF GENERATIVE THEORY FOR THE SCIENCE OF ASSESSMENT

The science of assessment is the scientific study of how to determine what people know (Anderson et al., 2001; Mayer, 2011; Pellegrino, Chudowsky, & Glaser, 2001). In this section, we describe two kinds of test items and three kinds of learning outcomes.

Two Kinds of Test Items

Table 1.5 summarizes two kinds of test items that can be used to assess what students have learned, based on the classic distinction between *retention* and *transfer*. Retention is the ability to recall or recognize what was presented. Thus, retention items are used when the goal is to assess how much of the presented material can be remembered. Transfer is the ability to apply what was learned to solve new problems. Thus, transfer items are used when the goal is to assess how well someone understands the presented material.

If we asked you to define *retention*, you could simply reproduce the second sentence of the preceding paragraph, which is an example of a retention

TABLE 1.5. *Two kinds of test items*

Item	Target	Description	Example
Retention	Remembering	Ability to recall or recognize what was presented	What is the definition of retention?
Transfer	Understanding	Ability to apply what was presented to solve new problems	Create a transfer item for this lesson.

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