e-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning, Fourth, Edition
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How Do People Learn from e-Courses?

CHAPTER SUMMARY

FROM GLITZY LAS VEGAS–STYLE GAMES at one extreme to page turners consisting of text on screens at the other, many e-learning courses ignore human cognitive processes and, as a result, do not optimize learning. In writing this book, we were guided by two fundamental assumptions: (1) the design of e-learning courses should be based on a cognitive theory of how people learn and (2) on scientifically valid research studies. In other words, e-learning courses should be constructed in light of (1) how the human mind learns and (2) experimental evidence concerning e-learning features that best promote learning. In this chapter we focus on the first assumption by describing how learning works and how to help people learn. In this edition, we have added a rationale for considering how learning works and a more detailed description of how instruction can be designed in light of obstacles to learning. Based on cognitive theories of how people learn, we focus on three instructional goals—minimize extraneous processing (cognitive processing unrelated to the instructional goal), manage essential

processing (cognitive processing to mentally represent the key material), and foster generative processing (deeper processing). The following chapter (Chapter 3) focuses on the second assumption by giving the rationale for evidence-based practice and by providing guidance for how to identify and use good research.

DESIGN DILEMMA: YOU DECIDE

Suppose you are in charge of the training department at Thrifty Savings and Loan. Your boss, the HR director, has just returned from an e-learning conference and asks you to develop a series of courses to be delivered via the corporate intranet: "With the recent merger, we need more cost-effective ways to deliver training to the local branches. We need to create both self-study lessons and virtual classroom sessions and to promote informal learning through social media. By using technology we can save money and also make learning fun. My kids really enjoy playing games online and connecting with others through Facebook and Twitter! Let's showcase our training to upper management by using the cutting edge of learning technology."

Your director of human resources is espousing what can be called a technology-centered approach to e-learning. For her, e-learning courses should take advantage of powerful, cutting-edge technologies such as mobile computing, video, games, and social media available on the web. In taking a technology-centered approach, she is basing her decisions about how to design e-learning courses on the capabilities afforded by new technologies.

Your intuition is that something is wrong with the technology-centered approach. In every era, strong claims have been made for the educational value of hot new technologies, but the reality somehow has never lived up to expectations. You wonder why there have been so many failures in the field of educational technology. Perhaps expectations have been unrealistic? Today, many of the same old claims about revolutionizing learning can be heard again, this time applied to online games, simulations, or to Web 2.0. You decide it's time to take a learner-centered approach, in which technology is adjusted to fit in with the way that people learn. But you wonder whether there is a learning theory with sufficient detail to guide tactical decisions in e-learning design.

Based on your own experience or intuition, which of the following options would you select?

A. Online applications such as games, simulations, and social media are engaging and should be a central feature of all new e-learning initiatives.

B. Online applications such as games, simulations, and social media may interfere with human learning processes and should be avoided.

C. We don't know enough about human learning to make specific recommendations about how to use new technology features.

D. Not sure which options are correct.

How Do People Learn?

Let's begin our review of what works in e-learning with a discussion of technology and learner-centered views of instruction.

Learning with Technology

Today, there is an impressive arsenal of instructional technologies that can be used, ranging from educational games played on mobile devices to virtual reality environments to online learning with animated pedagogic agents and with video and animation. Is there anything special about learning with technology? Examine the following questions about learning with technology and place a check mark next to the one you think is most important:

- ☐ How can we use cutting-edge technology in training?
- ☐ How can we leverage technologies that younger generations have grown up using?
- ☐ What are the best technologies for e-learning?
- ☐ How can we adapt technology to aid human learning?

If you checked any of the first three items, you appear to be taking a technology-centered approach to learning with technology. In a technology-centered approach, you focus on the capabilities of educational technology and seek to promote learning with technology (Mayer, 2009). For example, your goal is to incorporate cutting-edge technologies such as social media and mobile learning into your training repertoire.

What's wrong with this view of learning with technology? The problem is that when you focus too much on the role of the latest technology, you may ignore the role of the learner. Cuban (1986) has described the history of educational technology since the 1920s, including motion pictures in the 1920s, educational radio in the 1930s and 1940s, educational television in the 1950s, and programmed instruction in the 1960s. In each case, strong claims were made for the potential of the newest technology of the day to revolutionize education, but in each case that potential was not reached. The reason for the disappointing history of educational technology may be that instructors expected learners to adapt to the technology and therefore did not design learning environments that were consistent with how people learn.

If you checked the last item, you are taking a learner-centered approach to learning with technology. In a learner-centered approach the focus is on how people learn and technology is adapted to the learner in order to assist the learning process (Mayer, 2009). The rationale for taking a learner-centered approach is that it has been shown to be more effective in promoting productive learning. A learner-centered approach does not rule out the use of new technological innovations. It does, however, require the adapting of those innovations in ways that support human learning processes. In this book, we take a learner-centered approach, so in this chapter we begin by taking a look at how learning works.

What Is Learning and Instruction?

Consistent with the consensus among learning scientists (Mayer, 2011), we define learning as a change in the learner's knowledge due to experience. This definition has three main elements:

- Learning involves a change.
- The change is in what the learner knows.
- The change is caused by the learner's experience.

First, if you are involved in e-training, your job is to help people change. Change is at the center of learning. Second, the change is personal in that it takes place within the learner's information processing system. A change in what the learner knows can include changes in facts, concepts, procedures, strategies, and beliefs. You can never directly see a change in someone's knowledge, so you have to infer that someone's knowledge has changed by observing a change in behavior. Third, the change in what someone knows is caused by an instructional episode, that is, by a person's experience. If you are involved in e-training, your task is to design environments that create experiences that will foster desired change in learners' behaviors consistent with the goals of the organization. This definition of learning is broad enough to include a wide range of e-learning, including online PowerPoint presentations, virtual classrooms, simulations, and games. The goal of the science of learning is a research-based theory of how learning works.

We define instruction as the training professional's manipulation of the learner's experiences to foster learning (Mayer, 2011). This definition has two parts. First, instruction is something that the instructional professional does to affect the learner's experience. Second, the goal of the manipulation is to cause a change in what the learner knows. This definition of instruction is broad enough to include a wide range of instructional methods in e-learning, as described in the following chapters of this book. The goal of the science of instruction is a set of research-based principles for how to design, develop, and deliver instruction. Importantly, the job of the training professional is more than just presenting information to the learner, but also involves guiding the learner's cognitive processing of the material during learning.

Three Metaphors for Learning

Place a check mark next to your favorite description of how learning works:

- ☐ Learning involves strengthening correct responses and weakening incorrect responses.
- ☐ Learning involves adding new information to your memory.
- ☐ Learning involves making sense of the presented material by attending to relevant information, mentally reorganizing it, and connecting it with what you already know.

Each of these answers reflects one of the three major metaphors of learning that learning psychologists have developed during the past one hundred years, as summarized in Table 2.1 (Mayer, 2009). Your personal view of how learning works can affect your decisions about how to design instructional programs.

Table 2.1. Three Metaphors of Learning.

Adapted from Mayer, 2005.

Metaphor of Learning	*Learning Is:*	*Learner Is:*	*Instructor Is:*
Response Strengthening	Strengthening or weakening of associations	Passive recipient of rewards and punishments	Dispenser of rewards and punishments
Information Acquisition	Adding information to memory	Passive recipient of information	Dispenser of information
Knowledge Construction	Building a mental representation	Active sense-maker	Cognitive guide

If you checked the first answer, you opted for what can be called the response strengthening view of learning. In its original form, response-strengthening viewed the learner as a passive recipient of rewards or punishments, and the teacher as a dispenser of rewards (which serve to strengthen a response) and punishments (which serve to weaken a response). In Chapter 1 we referred to training based on a response-strengthening view as a directive instructional architecture. A typical instructional method is to present simple questions to learners, and when they respond tell them whether they are right or wrong. This was the approach taken with programmed instruction in the 1960s and is prevalent in some e-learning lessons today. Our main criticism of the response-strengthening metaphor is not that it is incorrect, but rather that it is incomplete—it tells only part of the story because it does not explain meaningful learning.

If you checked the second answer, you opted for what can be called the information-acquisition view of learning, in which the learner's job is to receive information and the instructor's job is to present it. A typical instructional method is a PowerPoint presentation, in which the instructor conveys information to the learner. In Chapter 1 we refer to the information-acquisition view as the basis for a receptive instructional architecture. This approach is sometimes called the empty vessel or sponge view of learning because the learner's mind is an empty vessel into which the instructor pours information. Our main criticism of this view—which is probably the most commonly held view among most people—is that it conflicts with much of what we know about how people learn. As we saw in Chapter 1, all learning requires psychological engagement—a principle that is often ignored in receptive learning environments.

If you opted for the third alternative, you picked a metaphor that can be called knowledge construction. According to the knowledge-construction view, people are not passive recipients of information, but rather are active sense-makers. Although we find some merit in each of the metaphors of learning, we focus most strongly on this one. In short, the goal of effective instruction is not only to present information but also to encourage the learner to engage in appropriate cognitive processing during learning.

Principles and Processes of Learning

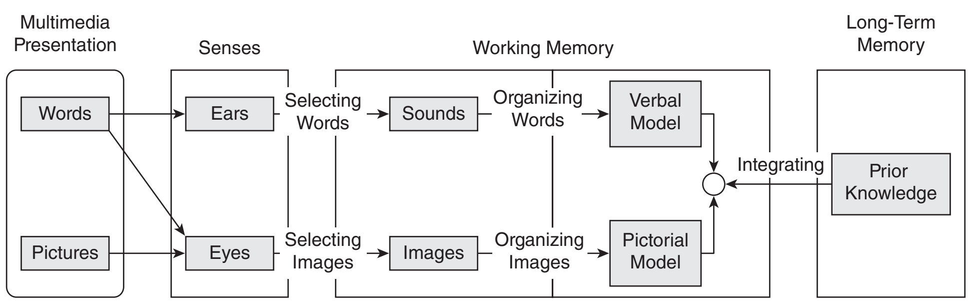
The knowledge construction view is based on three principles from research in cognitive science:

- *Dual channels*—people have separate channels for processing visual/pictorial material and auditory/verbal material,
- *Limited capacity*—people can actively process only a few pieces of information in each channel at one time, and
- *Active processing*—learning occurs when people engage in appropriate cognitive processing during learning, such as attending to relevant material, organizing the material into a coherent structure, and integrating it with what they already know.

Figure 2.1 presents a model of how people learn from multimedia lessons (Mayer, 2009, 2014c).

Figure 2.1. Cognitive Theory of Multimedia Learning.

Adapted from Mayer, 2014c.



As you can see, the dual channel principle is represented by the two rows—one for processing words (across the top) and one for processing pictures (across the bottom). The limited capacity principle is represented by the large Working Memory box in the middle of the figure, in which knowledge construction occurs. The active processing principle is represented by the five arrows in the figure—selecting words, selecting images, organizing words, organizing images, and integrating—which are the cognitive processes needed for meaningful learning.

Consider what happens when you are presented with a multimedia lesson. In the left column, a lesson may contain graphics and words (in printed or spoken form). In the second column, the graphics and printed words enter the learner's cognitive processing system through the eyes, and spoken words enter through the ears. If the learner pays attention, some of the material is selected for further processing in the learner's working memory—where you can hold and manipulate just a few pieces of information at one time in each channel. In working memory, the learner can mentally organize some of the selected images into a pictorial model and some of the selected words into a verbal model. Finally, as indicated by the *integrating arrow*, the learner can connect the incoming material with existing knowledge from long-term memory—the learner's storehouse of knowledge.

As you can see, there are three important cognitive processes indicated by the arrows in the figure:

- *Selecting words and images*—the first step is to pay attention to relevant words and images in the presented material,
- *Organizing words and images*—the second step is to mentally organize the selected material in coherent verbal and pictorial representations, and
- *Integrating*—the final step is to integrate incoming verbal and pictorial representations with each other and with existing knowledge.

Meaningful learning occurs when the learner appropriately engages in all of these processes.

Managing Limited Cognitive Resources During Learning

The challenge for the learner is to carry out these processes within the constraints of severe limits on how much processing can occur in each channel of working memory at one time. You may recall the expression from a classic paper by Miller (1956): "*Seven plus or minus two."* This refers to the capacity limits of working memory, that is, people can generally think about only a few items at any one time. Let's explore three kinds of demands on cognitive processing capacity (Mayer, 2009, 2011, 2014c; Sweller, Ayres, & Kalyuga, 2011):

- *Extraneous processing*—is cognitive processing that does not support the instructional objective and is created by poor instructional layout (such as having a lot of extraneous text and pictures),
- *Essential processing*—is cognitive processing aimed at mentally representing the core material (consisting mainly of selecting the relevant material) and is created by the inherent complexity of the material, and
- *Generative processing*—is cognitive processing aimed at deeper understanding of the core material (consisting mainly of organizing and integrating) and is created by the motivation of the learner to make sense of the material and can be supported by instructional methods that promote engagement with the material.

The challenge for instructional professionals is that all three of these processes rely on the learner's cognitive capacity for processing information, which is quite limited (Sweller, Ayres, & Kalyuga, 2011; Mayer, 2014c).

As summarized in Table 2.2, when you take the learner's limited cognitive capacity into account, you can be faced with three possible instructional scenarios: too much extraneous processing, too much essential processing, and not enough generative processing (Mayer, 2009, 2011, 2014c). First, in *extraneous overload*, the amount of extraneous and essential processing exceeds the learner's cognitive capacity, that is, the learner uses so much capacity on extraneous processing (for example, reading extraneous material) that there is not enough capacity remaining for essential processing (comprehending the essential material). The solution to this problem is to reduce extraneous processing such as by reducing unneeded material in the lesson (Mayer & Fiorella, 2014).

Second, in *essential overload*, even though extraneous processing has been minimized, the amount of required essential processing exceeds the learner's cognitive capacity. In short, the material is so complex that the learner lacks

Table 2.2. Approaches to Manage Challenges of Cognitive Load.

Challenge	*Description*	*Solution*	*Examples*
Too much extraneous processing	The cognitive load caused by extraneous and essential processes exceeds mental capacity	Use instructional methods that decrease extraneous processing	• Use audio to describe complex visuals • Write lean text and audio narration
Too much essential processing	The content is so complex that it exceeds cognitive capacity	Use techniques to manage content complexity	• Segment content into small chunks • Use pretraining to teach concepts and facts separately
Insufficient generative processing	The learner does not engage in sufficient processing to result in learning	Incorporate techniques that promote psychological engagement	• Add practice activities • Add relevant visuals

sufficient processing capacity. The solution to this problem is to manage essential processing with a technique such as breaking complex content into smaller learning chunks (Mayer & Pilegard, 2014).

Third, in *generative underutilization*, the learner does not engage in generative processing even though cognitive capacity is available, perhaps due to lack of motivation. The solution to this problem is to foster generative processing with techniques such as using conversational language (Mayer, 2014d). Asking students to elaborate on the material (as described in Chapters 11 and 13) or play educational games (as discussed in Chapter 17) also represents attempts to foster generative processing.

Overall, three goals for instructional designers are to create instructional environments that minimize extraneous cognitive processing, manage essential processing, and foster generative processing. Table 2.3 summarizes some techniques for addressing each goal and shows the chapter in this book that examines the technique.

Table 2.3. Techniques for Minimizing Extraneous Processing, Managing Essential Processing, and Fostering Generative Processing.

Goal	*Example Technique*	*Chapter*
Minimize extraneous processing	Coherence principle: Do not use unneeded words, sounds, or graphics.	8
	Contiguity principle: Place printed words near corresponding part of graphic.	5
	Redundancy principle: Use graphics and audio rather than graphics, audio, and on-screen text.	7
	Worked example principle: Provide step-by-step demonstrations	12
Manage essential processing	Segmenting principle: Break a continuous lesson into manageable parts.	10
	Pretraining principle: Provide pretraining in the names and characteristics of key components.	10
	Modality principle: Use audio rather than on-screen text.	6
Foster generative processing	Personalization principle: Use conversational style rather than formal style.	9
	Multimedia principle: Present words and graphics rather than words alone.	4
	Engagement principle: Ask learners to elaborate on the material.	11, 13

How e-Lessons Affect Human Learning

If you are involved in designing or selecting instructional materials, your decisions should be guided by an accurate understanding of how learning works. Throughout the book, you will see many references to cognitive learning theory, as described in the previous section. Cognitive learning theory explains how mental processes transform information received by the eyes and ears into knowledge and skills in human memory.

Instructional methods in e-lessons must guide the learners' transformation of words and pictures in the lesson through working memory so that they are incorporated into the existing knowledge in long-term memory. These events rely on the following processes:

1. Selection of the important information in the lesson.
2. Management of the limited capacity in working memory to allow the processing needed for learning.
3. Integration of auditory and visual sensory information in working memory with existing knowledge in long-term memory by way of processing in working memory.
4. Retrieval of new knowledge and skills from long-term memory into working memory when needed later.

In the following sections, we elaborate on these processes and provide examples of how instructional methods in e-learning can support or inhibit them.

Methods for Directing Selection of Important Information

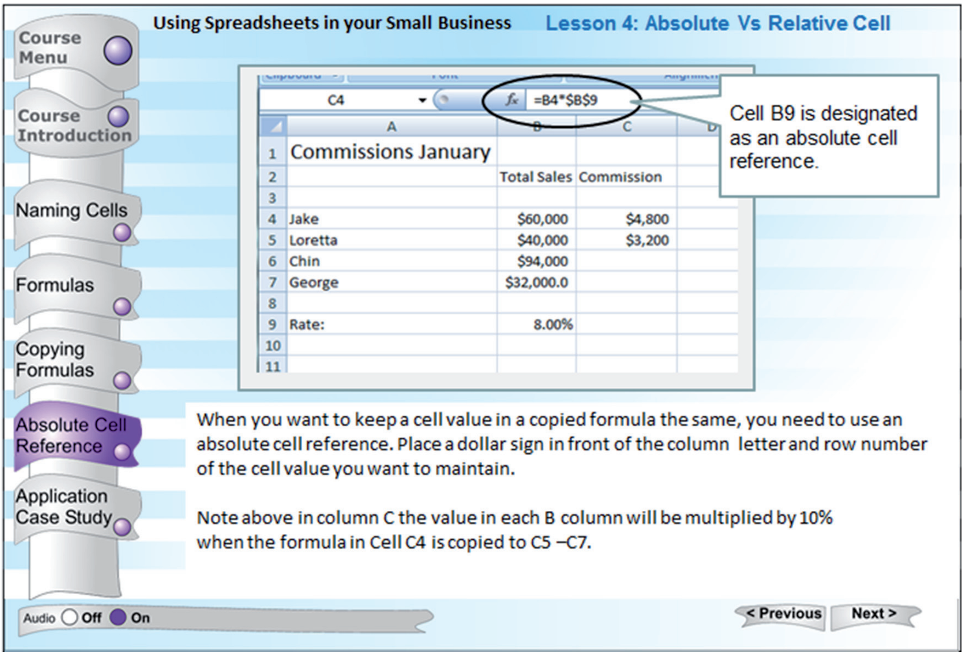
Our cognitive systems have limited capacity. Since there are too many sources of information competing for this limited capacity, the learner must select those that best match his or her goals. We know this selection process can be guided by instructional methods that direct the learner's attention. For example, multimedia designers may use a circle or color to draw the eye to important text or visual information, as shown in Figure 2.2.

Methods for Managing Limited Capacity in Working Memory

Working memory must be free to rehearse the new information provided in the lesson. When the limited capacity of working memory becomes filled, processing becomes inefficient. Learning slows and frustration grows. For example, most of us find multiplying numbers like 968 by 89 in our heads to be a challenging task. This is because we need to hold the intermediate products of our calculations in working memory storage and continue to multiply the next set of numbers in the working memory processor. It is very difficult for working memory to hold even limited amounts of information and process effectively at the same time.

Therefore, instructional methods that overload working memory make learning more difficult. The burden imposed on working memory in the

Figure 2.2. Visual Cues Help Learners Attend to Important Elements of the Lesson.



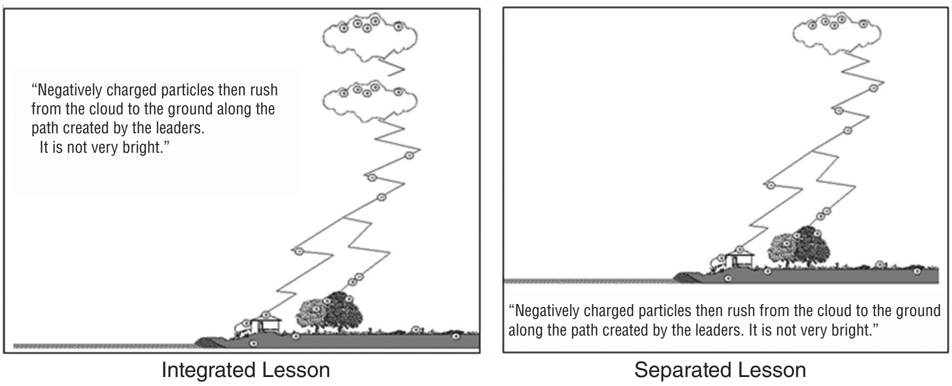
form of information that must be held plus information that must be processed is referred to as *cognitive load*. Methods that reduce cognitive load foster learning by freeing working memory capacity for learning. In the past ten years we've learned a lot about ways to reduce cognitive load in instructional materials. Many of the guidelines we present in Chapters 4 through 12 are effective because they reduce or manage load. For example, the coherence principle described in Chapter 8 states that better learning results when e-lessons minimize irrelevant or complex visuals, omit background music and environmental sounds, and use succinct text. In other words, less is more. This is because a minimalist approach that avoids overloading working memory allows greater capacity to be devoted to rehearsal processes leading to learning.

Methods for Integration

Working memory integrates the words and pictures in a lesson into a unified structure and further integrates these ideas with existing knowledge in long-term memory. The integration of words and pictures is made easier by lessons that present the verbal and visual information together rather than separated. For example, Figure 2.3 illustrates two screens from two versions of a lesson on lightning formation in which the text is placed next to the graphic (version A) or is placed at the bottom of the screen (version B). Version A (the integrated version) resulted in better learning than version B. Chapter 5 summarizes the contiguity principle of instruction that recommends presenting pictures and words close together on the screen.

Figure 2.3. Screens from Lightning Lesson with Integrated Text and Graphics (Left) and Separated Text and Graphics (Right).

Adapted from Mayer (2001a, 2005b)



Once the words and pictures are consolidated into a coherent structure in working memory, they must be further integrated into existing knowledge structures in long-term memory. This requires active processing in working memory. e-Lessons that include practice exercises and worked examples stimulate the integration of new knowledge into prior knowledge. For example, a practice assignment asks sales representatives to review new product features and identify which of their current clients are best suited to take advantage of a product upgrade. This assignment requires active processing of the new product feature information in a way that links it with prior knowledge about their clients.

Methods for Retrieval and Transfer

It is not sufficient to simply add new knowledge to long-term memory. For success in training, those new knowledge structures must be encoded into long-term memory in a way that allows them to be easily retrieved when needed on the job. Retrieval of new skills is essential for transfer of training.

Without retrieval, all the other psychological processes are meaningless, since it does us little good to have knowledge stored in long-term memory that cannot be applied later.

For successful transfer, e-lessons must incorporate the context of the job in the examples and practice exercises so the new knowledge stored in long-term memory contains good retrieval hooks. For example, one multimedia exercise asks technicians to play a Jeopardy™ game in which they recall facts about a new software system in response to clues. A better alternative exercise gives an equipment failure scenario and asks technicians to select a troubleshooting action based on facts about a new software system. The Jeopardy™ game exercise might be perceived as fun, but it risks storing facts in memory without a job context. These facts, lacking the contextual hooks needed for retrieval, often fail to transfer. In contrast, the troubleshooting exercise asks technicians to apply the new facts to a job-realistic situation. Chapters 12,13, and 16 on examples, practice, and scenarios in e-learning, respectively, provide a number of guidelines with samples of ways multimedia lessons can build transferable knowledge in long-term memory.

Summary of Learning Processes

In summary, learning from e-lessons relies on four key processes:

- First, the learner must focus on key graphics and words in the lesson to select what will be processed.
- Second, the learner must rehearse this information in working memory to organize and integrate it with existing knowledge in long-term memory.
- Third, in order to do the integration work, limited working memory capacity must not be overloaded. Lessons should apply cognitive load reduction techniques, especially when learners are novices to the new knowledge and skills.
- Fourth, new knowledge stored in long-term memory must be retrieved back on the job. We call this process transfer of learning. To support transfer, e-lessons must provide a job context during learning that will create new memories containing job-relevant retrieval hooks.

All of these processes require an active learner—one who selects and processes new information effectively to achieve the learning result. The design of the e-lesson can support active processing or it can inhibit it, depending on what kinds of instructional methods are used. For example, a lesson that applies a Las Vegas approach to learning by including heavy doses of glitz may overload learners, making it difficult to process information in working memory. At the opposite extreme, lessons that use only text fail to exploit the use of relevant graphics, which are proven to increase learning (as described in Chapter 4).

What We Don't Know About Learning

The study of learning has a long history in psychology, but until recently most of the research involved contrived tasks in laboratory settings, such as how hungry rats learned to run a maze or how humans learned a list of words. Within the last twenty-five years, however, learning researchers have broadened their scope to include more complex and real-world kinds of learning tasks, such as problem solving. What is needed is more high-quality research that is methodologically rigorous, theoretically based, and grounded in realistic e-learning situations. In short, we need research-based principles of e-learning (Mayer, 2009, 2004; Mayer & Fiorella, 2014; Mayer & Pilegard, 2014; Sweller, Ayres, & Kalyuga, 2011). This book provides you with a progress report on research-based principles that are consistent with the current state of research in e-learning.

DESIGN DILEMMA: RESOLVED

Your HR director wanted to launch an e-learning program with popular new technological features such as games, simulations, and social media. However, you were concerned that an unbalanced focus on technology would be counterproductive. We considered the following options:

A. Online applications such as games, simulations, and social media are engaging and should be a central feature of all new e-learning initiatives.

B. Online applications such as games, simulations, and social media may interfere with human learning processes and should be avoided.

C. We don't know enough about human learning to make specific recommendations about how to use new technology features.

D. Not sure which options are correct.

We believe that the right question is NOT whether popular online features such as games or simulations are good or bad ideas. Instead, we recommend that you take a learner-centered approach and consider how all technology features from graphics to games can be used in ways that support cognitive processes of selection, rehearsal, load management, and retrieval. In this book we will address all major technology features from a learner-centered perspective.

A week later you stop by the HR director's office for a follow-up meeting. You make your case: "Using the corporate intranet for learning is not the same as using the Internet for entertainment or socializing. We really need to shape the media to our purposes, not vice versa! It's going to cost a lot to develop this training and even more for the employees to take it. Can we risk spending that money on materials that violate research-proven principles for learning? Let's use e-learning as an opportunity to improve the quality of the training we have been providing by factoring in evidence of what works!"

WHAT TO LOOK FOR IN e-LEARNING

In terms of making theory-based choices, you should look for e-lessons that:

- Minimize extraneous processing.
- Manage essential processing (that is, attending to relevant information).
- Foster generative processing (that is, mentally organizing the material and integrating it with relevant prior knowledge).

In short, the lessons should support and guide the learner's cognitive processing during learning, including selecting, organizing, and integrating.

At the end of the remaining chapters, you will find in this section a checklist of things to look for in effective e-lessons. The checklists summarize teaching methods that support cognitive processes required for learning and that have been proven to be valid through controlled research studies. In Chapter 18 we present a comprehensive checklist that combines the guidelines from all of the chapters, along with some sample e-learning course critiques.

Chapter Reflection

1. Think of some e-learning projects or courses familiar to you. Was conscious consideration given to ways to manage essential cognitive processing as well as to minimize extraneous processing?

2. Take a look at Table 2.3. Based on your experience designing or taking e-learning courses, which instructional methods are familiar to you and which are new? Which chapters do you anticipate as most relevant to your needs?
3. In chapters to come we will describe how some of the instructional methods are more or less effective for low versus high prior knowledge learners. As you consider the three forms of cognitive load summarized in this chapter (extraneous, essential, and generative), how might these vary based on learner prior knowledge?

COMING NEXT

We derive the instructional principles in this book not only from a theory of how people learn but also from evidence of what works best. However, there are different types of evidence and some fundamental research concepts and techniques you should consider when you evaluate research claims. In the next chapter we summarize the basics of an evidence-based approach to e-learning.

Suggested Readings

Mayer, R.E. (2009). *Multimedia learning* (2nd ed.). New York: Cambridge University Press. *Summarizes evidence-based principles and theory for how to design online instruction.*

Mayer, R.E. (Ed.). (2014). *The Cambridge handbook of multimedia learning* (2nd ed.). New York: Cambridge University Press. *A compendium of current research and theory on how to design online instruction.*

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. New York: Springer. *Summarizes theoretical basis for evidence-based principles for how to design instruction.*

CHAPTER OUTLINE

What Is Evidence-Based Practice?

Three Approaches to Research on Instructional Effectiveness

What to Look for in Experimental Comparisons

How to Interpret Research Statistics

- Statistical Significance: Probability Less Than .05
- Practical Significance: Effect Size Greater Than .5

How Can You Identify Relevant Research?

Boundary Conditions in Experimental Comparisons

Practical Versus Theoretical Research

What We Don't Know About Evidence-Based Practice