

LEARNING BY VIEWING VERSUS LEARNING BY DOING: EVIDENCE-BASED GUIDELINES FOR PRINCIPLED LEARNING ENVIRONMENTS

Ruth Colvin Clark | Richard E. Mayer

A learner-centered approach is a central feature of instruction based on a constructivist learning model. However, there is some confusion regarding the requirement for behavioral activity as a prerequisite for a learner-centered environment. We offer evidence in this article that some types of behavioral activity can interfere with cognitive learning processes. We recommend that instructional professionals focus on cognitive activity and summarize evidence-based methods that support appropriate cognitive activity in behaviorally passive and active learning environments.

“FROM THE SAGE on the stage to the guide on the side” has been the mantra for instructional environments that emphasize behavioral activity as a prerequisite to effective learning. Terms such as *page-turner*, *passive learning environments*, and *didactic* carry negative connotations as being less effective compared to active learning environments such as games, collaborative learning, and immersive simulations.

What do you think about active and passive learning environments? Take our pretest in Exhibit 1 before you read this article.

Our message here is a simple one: physical activity does not equate to mental activity, and it is mental, not behavioral, activity that leads to learning. Specifically, engaging in online games, immersive simulations, or various forms of collaborative learning is not a guarantee of learning. Conversely, more passive environments, including text readings or lectures, do not preclude learning. Instead, it is the learner’s cognitive processing that leads to learning. What evidence do we have for our thesis? What are the features of any learning environment that support appropriate mental activity? These are the questions we address in this article.

HOW PEOPLE LEARN

The way we learn is constrained by our memory system. We have a limited capacity active processor, called *work-*

ing memory, and a large capacity repository of knowledge and skills, called *long-term memory*. Mayer (2005) and Clark and Mayer (2008) summarize three basic psychological principles associated with our memory system that underpin learning:

- *Dual coding principle*: Learners have separate learning channels for words and visuals.
- *Limited capacity principle*: Learners can process only a limited amount of information in working memory at any one time.
- *Active learning principle*: Learning occurs when learners engage in appropriate cognitive processing during learning.

Mayer (2005) summarizes the following processes that underlie learning:

- *Selecting* refers to attending to relevant aspects of the information coming into our cognitive system through our eyes and ears. Learners are able to focus on a limited subset of the environment from the large amount of information available at any one time. Selection of relevant information ensures that the learner focuses on important training content needed to build new knowledge and skills.
- *Organizing* refers to the active process of organizing words and pictures entering the senses from the learning environment into a coherent mental representation.

EXHIBIT 1 VIEWING VERSUS DOING PRETEST

Directions: Mark each statement as true or false.

1. Effective lessons incorporate frequent opportunities for learners to behaviorally interact with the content.	T	F
2. Games and simulations generally lead to better learning than page-turner e-learning lessons.	T	F
3. Animations are more effective for learning how things work than a series of still graphics.	T	F
4. Learning from text is generally better when students create their own content organizers than when content organizers are provided by the author.	T	F
5. The more practice, the better the learning.	T	F
6. Adding a relevant visual to text will improve learning.	T	F

- *Integrating* refers to the coordination of words and pictures with one another and with prior knowledge from long-term memory.

Whether training is delivered through an instructor, workbook, or computer, all effective instructional environments must accommodate and support these fundamental processes. For example, adding a relevant visual to a textual instructional message can improve learning as a result of dual encoding. In contrast, adding an interesting but irrelevant visual may depress learning because it interferes with selection of relevant information, as well as with the integration needed to build a coherent new mental model. The goal of instructional professionals is to select instructional methods proven to support these psychological learning processes.

Cognitive load theory, originated by John Sweller (2005), is a contemporary comprehensive instructional theory that explains the effectiveness of various instructional methods in terms of how they succeed or fail to accommodate the limited capacity of working memory. Specifically, Mayer (2005) describes three types of cognitive processing that can contribute to cognitive load:

- *Extraneous cognitive processing* comes from imposing content or work on working memory that is irrelevant to the learning objective. For example, irrelevant visuals can take up limited processing resources and hence depress learning. Instructional methods that require extraneous cognitive processing during learning should be minimized.

- *Essential cognitive processing* originates from the complexity of the instructional content and learning goals. Although essential cognitive processing is tied to content, it can be managed. For example, an instructor can divide large content repositories into small lesson segments.
- *Generative cognitive processing* occurs when a learner engages in deep processing in working memory in service of the learning goal, such as organizing the material and integrating it with prior knowledge. For example, an effective practice exercise can foster generative processing.

Overall, instructional methods should be used that minimize extraneous load and manage essential load freeing working memory capacity for generative load.

EMBRACING EVIDENCE-BASED INSTRUCTION

Trends and folk wisdom have served as the main source of instructional strategies for many years. However, we are seeing a shift to evidence-based practice. For example, Educause includes the following among its top 10 priorities for 2008 (Campbell & Oblinger, 2007):

1. Establish and support a culture of evidence.
2. Demonstrate improvement of learning.
3. Translate learning research into practice.

We recommend that instructional professionals responsible for effective learning integrate best practice research data into their design and development decisions. Although there are many sources of evidence, experimental evidence is our preferred resource for determining which instructional methods are more effective than others. The amount of experimental evidence to guide practitioner decisions has been growing in the past 25 years, so that today we have an extensive body of data from which to make instructional recommendations. Some resources that summarize this research follow:

Clark, R.C. (in press). *Building expertise* (3rd ed). San Francisco: Jossey-Bass/Pfeiffer.

Clark, R.C., & Kwinn, A. (2007). *The new virtual classroom*. San Francisco: Jossey-Bass/Pfeiffer.

Clark, R.C., & Mayer, R.E. (2008). *E-learning and the science of instruction* (2nd ed). San Francisco: Jossey-Bass/Pfeiffer.

Mayer, R.E. (2004). Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction. *American Psychologist*, 59(1), 14–19.

Mayer, R.E. (Ed.). (2005). *The Cambridge handbook of multimedia learning*. Cambridge: Cambridge University Press.

Mayer, R.E. (2008). *Learning and instruction* (2nd ed.). Upper Saddle River, NJ: Pearson Merrill Prentice Hall.

Mayer, R.E. (in press). *Multimedia learning* (2nd ed). New York: Cambridge University Press.

WHEN VIEWING IS BETTER THAN DOING

Contrary to the popular idea that learning demands behavioral activity and that lectures and page-turner e-learning are ineffective, we summarize experimental evidence from studies in which viewing leads to as good or even better learning than doing:

- When examples are more effective than practice.
- When author-provided graphics are better than learner-generated graphics.
- When learning from a lecture is as effective as learning from collaborative discussions.
- When still visuals are better than animations.

Does Practice Make Perfect?

Today many instructional professionals assume that effective learning requires frequent behavioral responses, such as responding to online questions, participating in group collaboration, or engaging in immersive simulations. For example, basic skill lessons focused on mathematics or technical skills (e.g., spreadsheet or database construction) traditionally include many practice problems. However, completing practice exercises imposes considerable mental work—work that can often take up so much working memory that there is little left over for the selecting, organizing, and integrating processes essential to learning.

In the mid-1980s, research psychologists found that learning was faster and better when some practice problems were replaced by worked-out examples that demonstrated the lesson skills. Sweller and Cooper (1985) found that test errors were cut in half when 12 math practice problems were replaced by 6 worked-out examples, each followed by practice.

Many experiments showing the benefits of examples to replace some practice are the basis of our first viewing-versus-doing principle: *Include a combination of examples and practice exercises rather than all practice*. For example, in a lesson on how to use Excel formulas, include an example showing the steps to construct and enter a formula, followed by practice in which the learner must construct and enter a formula. When the learner is viewing an example, working memory is free to build a new mental model of the skill. Then the learner can try out the new mental model in a practice problem.

Should Learners Provide Their Own Graphic Aids?

Suppose you were designing a lesson that presented a number of related concepts. To help learners organize this new knowledge, you could present an occasional graphic organizer, such as the one shown in Figure 1. Alternatively, you could engage the learner by providing an organizer template and asking the learner to write the correct labels into it. Stull and Mayer (2007) provided learners with a text passage from a biology textbook in which graphic organizers were either provided by the author or readers filled in the words themselves. Three experiments used varying numbers of graphic organizers for a 1,133-word text ranging from 27 organizers in the most complex lesson to 10 in the least complex lesson.

As expected, in all three experiments, learning times were greatest among those who had to generate their own organizers. Did this investment in active learning pay off? In fact, learning was best in all three experiments among those who reviewed author-provided graphic organizers.

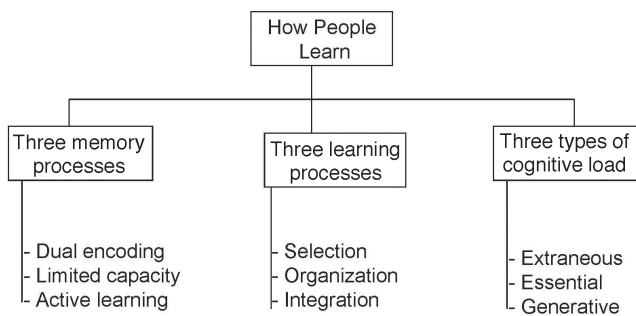


FIGURE 1. A GRAPHIC ORGANIZER

The research team concluded, “We found no support for the general proposition that learning by doing will always lead to deeper learning than learning by viewing, even though interest in discovery-based methods is still intense” (Stull & Mayer, 2007, p. 817).

The results from these comparisons of author-provided with learner-generated graphic organizers are the basis for our second viewing-versus-doing principle: *Include graphic organizers in your instructional materials that will help learners understand the relationships among topics in your content.*

Are Discussions Better Than Lectures?

Collaborative learning environments that use various types of synchronous or asynchronous work among class participants represent one popular approach to active learning. Yet research has not found benefits for collaborative learning in all situations. For example, Haidet, Morgan, O’Malley, Moran, and Richards (2004) compared immediate and delayed learning gains (pre- to posttest) among medical residents from instruction on the effective use of diagnostic tests. One group of residents attended a one-hour lecture, and the other engaged in group discussions of relevant clinical problems followed by an instructor case resolution that incorporated the same information as the lecture group. Both groups had significant gains in knowledge, immediately after the class and a month later. However, gains were equal in both groups: there were no statistically significant learning advantages for those in the active discussion group. In addition, learners in the active session gave lower ratings of the value and effectiveness of active sessions than those in the lecture version. These data are the basis for our third viewing-versus-doing principle: *Learning can be as effective from a didactic lecture environment as from a collaborative active environment.*

Are Animations Better Than Still Visuals?

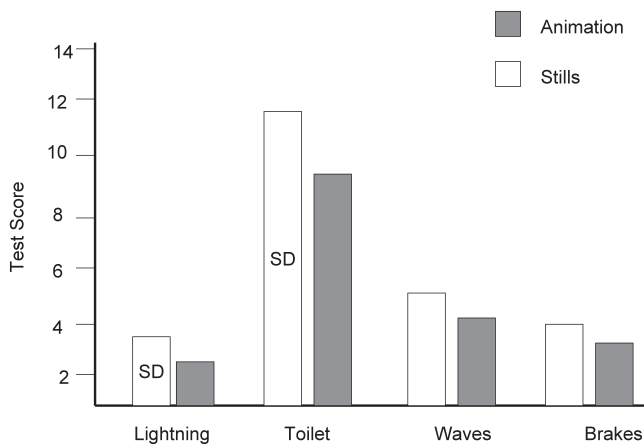
Imagine that you wanted to learn how a toilet tank flushes. You could review a series of still visuals explained

To illustrate how things work, a series of still visuals is likely to lead to as good or better understanding of the process than animations.

by text or an animation explained by audio narration. From PowerPoint to Captivate to Flash, modern multimedia development tools make animations relatively easy to produce. It seems intuitive to use an animation to display how something works, such as how a toilet flushes or how equipment functions. What evidence do we have about the teaching effectiveness of animated versus still visuals?

Mayer, Hegarty, Mayer, and Campbell (2005) summarized four experiments that compared learning from a computerized animated display to learning from a series of still visuals presented in print media. The lessons focused on teaching how toilet tanks work, how lightning develops, how ocean waves work, and how a car’s braking system works. After viewing the lesson, learners took problem-solving tests that required them to apply their understanding of how the equipment worked. For example, in the toilet tank lesson, learners were asked, “Suppose you push down on the handle of the toilet tank but water does not flush into the toilet bowl. Explain all of the possible things that could be wrong.” As you can see in Figure 2, the still visuals presented on paper resulted in better learning than the animated version in all cases. In the lightning and toilet lessons, the differences were statistically significant. Here we see a paradox in which a more passive medium (print with still visuals) led to deeper learning than a more active medium (computer with animation). The research team concludes, “Animation may be entertaining, but these experiments offer no reason to conclude that animation inherently provides more educational value than static diagrams. Instead, a well-designed series of still frames can be as good or better than animation” (p. 264).

Why would static animations lead to deeper learning? Possibly because the amount of visual and auditory information that a learner must absorb in an animated lesson exceeds working memory capacity to select, organize, and integrate the critical information. In addition, learners who are viewing a series of still visuals may mentally animate the pictures themselves. Thus, they may be experiencing greater psychological engagement with a more



Source: Based on data from Mayer, Hegarty, Mayer, and Campbell, 2005.

FIGURE 2. TRANSFER LEARNING GAINS FROM ANIMATED VERSUS STILL GRAPHICS

passive medium (print) compared to one that does all of the work for them (computer).

Nevertheless, do not conclude that animations are never effective. Their effectiveness may depend on the type of content being displayed or how the animation is designed. For example, an animation that uses cues to direct learner attention to important elements as well as incorporates pause and replay functionality may result in better learning. We need additional research to determine the main conditions under which animations are effective. For now, assuming that a more active display such as an animation is always more effective than a more traditional text display is a flawed conclusion. The improved learning outcomes resulting from a series of static visuals are the basis for our fourth viewing-versus-doing principle: *To illustrate how things work, a series of still visuals is likely to lead to as good or better understanding of the process than animations.*

MENTAL VERSUS PHYSICAL ACTIVITY

We use the four research studies just examined to support our claim that physical activity per se is not a prerequisite for learning. Instead, learning requires appropriate mental processing that includes selecting the important elements of a learning display, organizing the words and visuals into a coherent message, and integrating the new instructional content with existing knowledge in long-term memory to result in a deeper understanding. Figure 3 summarizes our activity grid. Instructional professionals must create instructional environments that promote high levels of psychological activity congruent with the learning objectives. They can use explicit instructional methods that

promote cognitive activity during learning while involving overt behavioral activity, or use implicit instructional methods that promote mental processes in the absence of behavioral activity.

Build Principled Presentations

The upper-left corner of Figure 3 refers to instructional presentations that promote mental processing in the absence of behavioral learner responses. For example, previously we determined that including worked examples that learners can study and use as the basis for mental models will improve learning more than using lessons that include all practice. Similarly, a well-designed lecture can lead to as much learning as discussion groups. When preparing materials for presentations, we recommend embedding instructional methods proven to support the processes of attention, organizing, and integrating. Over 15 years, Mayer (2005, in press) has derived a series of multimedia principles proven to enhance learning. Applying the guidelines summarized in Table 1 results in principled presentations.

To apply these principles, begin by incorporating relevant visuals that help learners build deeper mental models through dual encoding. Explain complex visuals with instructor narration rather than with text to reduce essential load on the visual channel of working memory. However, when audio narration is not feasible, place explanatory text nearby relevant parts of the visual to minimize extraneous load. Visuals, audio, and extra words that are not relevant to the learning objective can impose extraneous load and should be avoided. Words, in either audio or text format, should reflect a conversational tone to promote deeper learning.

Figure 4 shows a PowerPoint slide from a lesson on constructing databases that applies these principles. It incorporates a visual that is explained by an on-screen

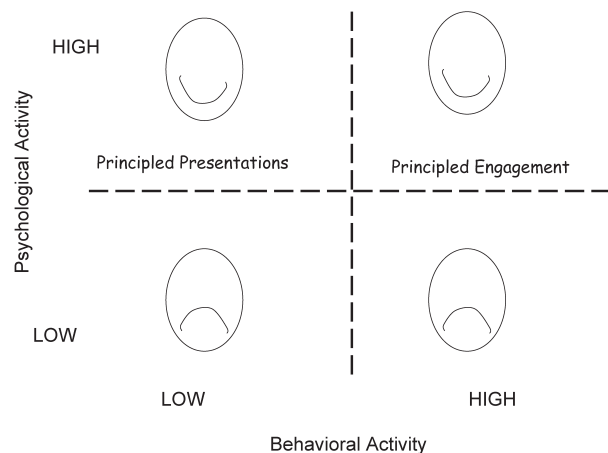


FIGURE 3. THE ACTIVITY GRID

TABLE 1 MAYER'S MULTIMEDIA PRINCIPLES	
PRINCIPLE	WHEN LEARNING IS BETTER
Multimedia	Instruction includes relevant visuals and words rather than words alone.
Contiguity	Text is aligned in close proximity to visuals.
Modality	Complex visuals are explained by audio rather than by text.
Redundancy	Complex visuals are explained by audio or by text rather than by both text and audio that narrates the text.
Coherence	Extraneous visuals, words, and sounds are omitted.
Personalization	Learners are socially engaged through conversational language and on-screen learning agents.
Pretraining	Key concepts are explained prior to the full process or task associated with the concepts.
Segmenting	Content is presented in short sequences over which the learner controls the rate of access.

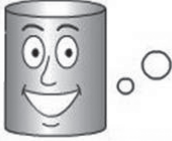
Designing a Relational Database

Table Construction Jump to a Topic Table Construction

	A	B	C	D	E	F	G	H	I	J	K
1	Video Store Movie Rentals										
2											
3	First Name	Last Name	Address	Zip	Phone	D.O.B.	Gender	Movie Rented	Rental Date	Return Date	Movie Genre
4	Sally	Jones	124 Mission St.	86242	555-4688	1/24/1988	Male	Under Water	2/16/2005	12/9/2005	Drama
5	Barbara	Smith	5 Thomas Blvd.	86248	555-7696	2/15/1969	Female	The Flying Circus	2/12/2004	2/19/2004	Action
6	Ralph	Johnson	1209 North Street	86445	555-1254	3/27/1978	Male	West Roads	3/17/2005	3/25/2005	Drama
7	Elizabeth	Wilson	16 West Street Dr.	86704	555-9811	7/4/1991	Female	The Princess	4/18/2005	4/25/2005	Drama

↑

We start by looking at the raw data in the spreadsheet and choosing the characteristics that uniquely pertain to customers. In Sally's case, the relevant customer information is circled in red.



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My Compu

Source: Clark and Mayer, 2008.

FIGURE 4. A PRINCIPLED POWERPOINT SLIDE

agent narration using a conversational tone. To support attention, the visual is signaled with an arrow and circle. Whether this slide is used in a face-to-face classroom, an online virtual classroom, or an asynchronous digital lesson, learning should be better than from a slide that lacks a visual or uses an irrelevant visual explained with text or with audio and redundant text.

Build Principled Behavioral Interactions

We do not advocate abandoning active learner participation during instruction! The upper right corner of Figure 3 represents instructional methods that foster both high behavioral activity and high psychological activity during learning. There is ample evidence that behavioral activity can lead to appropriate cognitive processing during learning provided that such activity applies evidence-based guidelines summarized in Table 2.

In brief, behavioral activities should require learners to engage in mental processes that are congruent with the learning outcomes in ways that do not overload working memory with extraneous work. For example, in spite of continued enthusiasm for discovery learning environments such as some types of immersive learning simulations, instructional events that fail to offer sufficient guidance have a long history of documented failure (Mayer, 2004). Similarly, a quiz show or rapid-response game can elicit a great deal of behavioral activity but be counterproductive to learning objectives that benefit from conceptual understanding and reflection.

Second, to aid retrieval of new knowledge, behavioral activities should require learners to respond in ways that are congruent with the transfer environment. Activities

that ask learners to parrot content out of application context are unlikely to promote transfer of learning beyond the instructional setting.

Third, distributing practice exercises throughout a learning event is proven to lead to significantly better long-term retention. For example, if a lesson has 12 practice exercises, long-term learning will be better if the 12 exercises are distributed within the lesson and among lessons to follow rather than all in one place.

Finally, explanatory feedback to learner responses leads to better learning than merely telling learners that their response is correct or incorrect (Moreno, 2004; Moreno & Mayer, 2005).

Figure 5 shows an online practice exercise from a lesson on constructing databases. This interaction is application focused: it requires the learner to apply the concept of records to a scenario and offers explanatory feedback.

THE BOTTOM LINE

Learning depends on appropriate psychological activity, not behavioral activity. Instructional environments, whether they are behaviorally active or passive, benefit from incorporating evidence-based methods to promote productive mental activity during learning. It does not make sense to categorize traditionally passive environments such as texts and lectures as ineffective. Conversely, high-engagement environments such as multimedia simulations are not inherently effective. Instructional professionals must look beneath the surface of any learning environment and embed proven principles that lead to productive psychological engagement.

TABLE 2 EVIDENCE-BASED METHODS FOR BEHAVIORAL ENGAGEMENT

PRINCIPLE	SUMMARY
Minimize extraneous work	Avoid behavioral engagement that adds irrelevant mental load that conflicts with the learning objectives. For example, avoid discovery environments that waste mental resources.
Mirror the application environment	Develop behavioral engagement strategies that incorporate the physical and psychological context of the application environment. For workforce learning, engagement should reflect the context of the job.
Distribute exercises	The same number of practice exercises distributed within and among lessons will lead to better long-term retention than when the exercises are located in a single time and place in the lesson.
Offer explanatory feedback	Provide tailored explanations for all correct and incorrect answers.

Designing a Relational Database


Table Construction Jump to a Topic Entities and Tables

Customers Table

First	Last	Address	Zip	Phone	D.O.B.	Gender
Alex	Jones	123 Wilson St.	85042	555-4589	12/14/1970	Male
Harriet	Smith	478 Glenn Ave.	85043	555-9631	6/29/1974	Female
Wendy	Martin	558 Tube St.	85261	555-9800	12/16/1985	Female

How many additional records would need to be added to the table if the video store had a total of 50 customers?

2
 5
 50
 47



Sorry, that is incorrect. Remember, records are analogous to rows in a spreadsheet. Try again.

Audio Screen 18 of 49

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Source: Clark and Mayer, 2008.

FIGURE 5. A PRINCIPLED BEHAVIORAL ACTIVITY

REVISITING THE PRETEST

Here are our answers to the pretest in Exhibit 1:

1. Effective lessons incorporate frequent opportunities for learners to behaviorally interact with the content.
False. We have seen that behavioral activity does not necessarily translate into psychological activity, and it is appropriate psychological activity that leads to learning.
2. Games and simulations generally lead to better learning than page-turner e-learning lessons.
False. There is ample reason to believe that games and simulations can provide powerful learning environments. However, they may or may not lead to better learning than a traditional lesson depending on how effectively they support the core psychological processes underlying learning.
3. Animations are more effective for learning how things work than a series of still graphics.
False. So far, we lack evidence that animations are better than still visuals for learning processes. In fact, animations may overload working memory with too much visual and auditory information presented too quickly to allow adequate processing in working memory.

4. Learning from text is generally better when students create their own content organizers than when content organizers are provided by the author.

False. Learners benefit when the content author presents graphic organizers. Graphic organizers provide cognitive aids that can help learners process new content. Asking learners to generate their own organizers can impose extraneous load that interferes with learning.

5. The more practice, the better the learning.

False. Learning is more efficient when worked-out examples are interspersed with practice assignments. When learners view a worked-out example, working memory resources can be fully dedicated to processing the content. In contrast, when they are solving problem after problem, their working memory resources are absorbed by the amount of work required.

6. Adding a relevant visual to text will improve learning.

True. Incorporating relevant visuals into lessons applies the multimedia principle and improves learning through dual encoding.

Whether instruction takes place in a classroom or online or in a text reading, learning is strengthened by principled presentations that promote active psychological processes during learning. 🌟

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RUTH COLVIN CLARK has helped workforce learning practitioners apply evidence-based training guidelines to the design and development of classroom and e-learning instruction for over 25 years. She has developed a number of seminars and written or coauthored six books that translate important research programs into practical training guidance, including *e-Learning and the Science of Instruction*, *Efficiency in Learning*, and *The New Virtual Classroom*. She completed her doctorate in instructional psychology/educational technology at the University of Southern California. She is a past president of the International Society for Performance Improvement (ISPI) and a member of the American Educational Research Association. She was honored with the 2006 Thomas F. Gilbert Distinguished Professional Achievement Award by the ISPI and was a Training Legend Speaker at the ASTD 2007 International Conference. She may be reached at Ruth@Clarktraining.com.

RICHARD E. MAYER is professor of psychology at the University of California, Santa Barbara, where he has served since 1975. His research interests are in educational psychology, with a focus on learning, instruction, and technology. He is vice president for Division C (Learning and Instruction) of the American Educational Research Association, past president of the Division of Educational Psychology of the American Psychological Association, and recipient of the E. L. Thorndike Award for career achievement in educational psychology. In 2008 he received the American Psychological Association's Distinguished Contributions of Applications of Psychology to Education and Training Award, and in 2004 he was ranked number one as the most productive educational psychologist by *Contemporary Educational Psychology*. He has written 23 books and more than 250 articles and chapters, including *Multimedia Learning* (2001, in press), *Learning and Instruction* (2003, 2008), *e-Learning and the Science of Instruction* (with R. Clark, 2003, 2008), and *The Cambridge Handbook of Multimedia Learning* (editor, 2005). He may be reached at mayer@psych.uscb.edu.