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*Interview*

# An Interview with Richard Mayer

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Richard E. Mayer is professor of psychology at the University of California, Santa Barbara (UCSB), where he has served since 1975. He received a Ph.D. in psychology from the University of Michigan, in 1973, and served as visiting assistant professor of psychology at Indiana University, from 1973 to 1975. He is past-president of the Division of Educational Psychology of the American Psychological Association, former editor of *Educational Psychologist* and former co-editor of *Instructional Science*, former chair of the UCSB Department of Psychology, and the year 2000 recipient of the E. L. Thorndike Award for career achievement in educational psychology. He was ranked #1 as the most productive researcher in the field of educational psychology for 1991–2001 (*Contemporary Educational Psychology*, Vol. 28, pp. 422–430). Prof. Mayer is the author of 18 books and more than 250 articles and chapters, including *The Promise of Educational Psychology: Vols. 1 and 2* (1999, 2002), *Multimedia Learning*, (2001), *Learning and Instruction* (2003), and *E-Learning and the Science of Instruction* (with R. Clark, 2003). He serves on the editorial boards of 11 journals mainly in educational psychology. For the past 35 years he has conducted research on how instructional methods affect learning, and in the past 15 years, his research has focused on multimedia learning. In this interview, he discusses his current research agenda concerning multimedia learning and responds to critical questions regarding web-based instruction and the nature of educational research.

*Q: What are your current research interests*?

A: My research interests are at the intersection of cognition (e.g., how people learn), instruction (e.g., how to help people learn), and technology

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(e.g., how to design computer-based graphics to help people learn). My goal is to develop a theory of how people learn from words and pictures, and to develop research-based principles for the design of multimedia learning environments that are consistent with how people learn. Currently, I am involved in several research projects: (a) the role of verbalizer-visualizer cognitive style in on-line training (sponsored by the Office of Naval Research), (b) the design of socially intelligent on-screen agents (sponsored by the National Science Foundation), (c) the role of computer-based instructional technology in improving student learning in college courses (sponsored by the Mellon Foundation), and (d) comparisons of how students learn from animation and narration versus static diagrams and printed text.

*Q: What is your cognitive theory of multimedia learning, and how does it relate to the design of on-line instruction*?

A: The cognitive theory of multimedia learning explains how people learn from words (such as printed text or spoken text) and pictures (such as illustrations, photos, charts, animation, or video). It is based on three assumptions derived from research in cognitive science: dual channels, that is, people have separate channels for processing visual and verbal material; limited capacity, that is, people are able to process only a few elements in each channel at any one time; and generative processing, that is, meaningful learning occurs when learners engage in appropriate cognitive processing during learning, such as selecting relevant information, mentally organizing the selected information into coherent pictorial and verbal models, and integrating them with each other and with prior knowledge.

There are five main cognitive processes in the cognitive theory of multimedia learning: selecting words, selecting images, organizing words, organizing images, and integrating. Selecting words occurs when the learner pays attention to some of the verbal material entering through the ears (i.e., spoken text) for further processing in the verbal channel of working memory. Selecting images occurs when the learner pays attention to some of the visual material entering through the eyes (i.e., pictures or printed words) for further processing in the visual channel of working memory. In working memory, the visual representation of the printed words can be converted into sounds of the words in the verbal channel and verbal representations can be converted into pictorial ones. Organizing words involves building a verbal model, that is, a coherent structure containing some of the selected verbal material in the verbal channel. Organizing images involves building a pictorial model, that is, a coherent structure containing some of the selected pictorial material in the visual channel. Finally, integrating involves building connections between the verbal and pictorial models and with prior knowledge from long-term memory.

The main challenge of instructional design is to present material in a way that promotes generative processing without overloading the capacity of the learner's information processing system. I explain the model in more detail in *Multimedia Learning* and in the forthcoming *Cambridge Handbook of Multimedia Learning.*

*Q: What are some research-based principles of instruction derived from cognitive theories of multimedia learning*?

A: Based on more than 80 experimental comparisons, I have developed a collection of 10 research-based principles for the design of multimedia instructional messages. Five principles are aimed at reducing extraneous cognitive processing (i.e., processing that is not related to the instructional goal): coherence principle, signaling principle, redundancy principle, spatial contiguity principle, and temporal contiguity principle. The coherence principle is that people learn more deeply when extraneous words, pictures, and sounds are eliminated rather than included. The signaling principle is that people learn more deeply when the important words are highlighted rather than not. The redundancy principle is that people learn more deeply from animation and narration than from animation, narration, and on-screen text. The spatial contiguity principle is that people learn more deeply when corresponding portions of the picture and printed words are near rather than far from each other on the page or screen. The temporal contiguity principle is that people learn more deeply when corresponding portions of the animation and narration are presented simultaneously rather than successively.

Three principles are aimed at managing intrinsic cognitive processing (i.e., basic processing related to the instructional goal): segmenting principle, pre-training principle, and modality principle. The segmenting principle is that people learn more deeply when a narrated animation is presented in learner-paced segments rather than as a continuous unit. The pre-training principle is that people learn more deeply when they have had training in the names and characteristics of the main concepts. The modality principle is that people learn more deeply from animation and narration than from animation and on-screen text.

Two principles are aimed at promoting generative processing (i.e., deeper and more reflective processing related to the instructional goal) through social cues: personalization principle and voice principle. The personalization principle is that people learn more deeply when the words are presented in conversational style rather than formal style. The voice principle is that people learn more deeply when the words are spoken in a non-accented human voice rather than a machine simulated voice or a foreign-accented human voice. I describe the research supporting these principles in *Multimedia Learning* and in the forthcoming *Cambridge Handbook of Multimedia Learning.*

*Q: Did you ever have to revise any of the multimedia principles when you were developing your theory*?

A: Of course, the principles we proposed sometimes have changed based on the available research evidence. In general, we do not offer a principle until it has been tested in a series of experiments. For example, in a recent review, I noted that the modality principle (i.e., the idea that people learn more deeply from animation and narration than animation and on-screen text) was tested and supported in more than two dozen experiments. In contrast, we have not been able to find support for the image principle (i.e., the idea that people learn more deeply when a conversational agent is portrayed on the screen rather than not), in spite of advocacy for the principle among some computer scientists. We also have had difficulty in finding consistent evidence for an individual difference principle, in which high spatial ability students learn more deeply from well-designed multimedia lessons than do low spatial ability students. Finally, I suspect that we will have to modify the voice principle (i.e., the idea that people learn more deeply from a standard-accented human voice than a machine simulated voice or foreign-accented voice) when we examine the role of voice in a long-term instructional program. What makes this line of research fun for us is that there is such a need for collecting data to test our principles and the cognitive theory of multimedia learning from which they are derived.

*Q: Is instruction technology centered or learner centered*?

A: Instruction should be learner-centered rather than technology-centered. In taking a learner-centered approach, you begin with what is known about how people learn and then try to employ technology in ways that assist human learning. According to this view, technology is a learning tool that is adjusted to fit the needs of learners. In taking a technology-centered approach, you begin with a cutting edge technology and then try to make it available to students. According to this view, technology is a treasure that should be applied to instruction. The problem with the technology-centered approach is that it is more concerned with promoting educational technology than with promoting learning in students.

*Q: What are the strengths and weaknesses of learning with technology*?

A: This is an often-asked question, but it is probably not a fruitful one. In my opinion, technology does not cause learning, but rather instructional methods cause learning. Instructional technologies such as computer-based lessons and paper-based lessons tend to foster the same learning outcomes in learners if both technologies employ the same instructional methods. Instructional methods that result in poor learning in a paper-based environment tend to also result in poor learning in a computer based environment, and instructional methods that result in good learning in a paper-based environment tend to also result in good learning in a computer-based environment. Thus, our efforts should be directed at determining which instructional methods have which learning effects on which learners under which conditions.

In some cases, of course, certain "cutting edge" technologies can afford instructional methods that are not possible (or are much more difficult to implement) with older technologies. For example, on-line digital libraries offer instructional opportunities to access information that would be impossible or, at least, time-consuming using traditional technologies. Thus, an important research question is: Which instructional methods are most effective in helping people learn with digital libraries? Even when new technologies enable new instructional methods, sometimes the instructional methods afforded by a "cutting edge" technology may not be more effective than methods afforded by older technologies. For example, there is no strong evidence that students learn better from computer-based animation than from a series of still frames printed on paper.

Overall, it is not fruitful to ask whether a particular technology is better than another. Asking whether computers are a good instructional technology is like asking whether books are a good instructional technology. It all depends on how they are used, that is, on the instructional method. Thus, the goal of research in educational technology is the same as research in educational psychology in general—that is, to determine how various instructional methods affect student learning.

Another reason that this question may be somewhat fruitless is that most instructional scenarios involve some form of technology. When a teacher writes on a blackboard, the student is learning with "chalk technology." When a student reads a textbook, the student is learning with "print technology." Even when a lesson involves discussion, the student is learning with an important cognitive technology, namely language. So, I believe this question about the strengths and weaknesses of instructional technology is probably really asking about cutting edge technologies such as interactive, highly graphic, computer-based technologies. Yet, the same answer applies: technology matters only to the extent that it may allow new instructional methods. Comparing the effects of various instructional methods on student learning is therefore a central task in the domain of educational psychology.

*Q: What is "good" research?*

A: This is an important question that is at the heart of our domain. Good research in educational psychology (a) addresses an important educational issue, (b) begins with a testable theory, (c) uses an appropriate and rigorous methodology, (d) generates useful data, and (e) employs logical reasoning. First, the topic of the research should be educationally relevant, such as, asking whether adding graphics to text can enhance student learning. In short, the research should have the potential to contribute to educational practice.

Second, the research should be grounded in a testable theory, such as the cognitive theory of multimedia learning [as described in Mayer, R. E. (2001). *Multimedia learning*. New York: Cambridge University Press]. It is important not to confuse testable theories with untestable doctrine. Citing broad frameworks such as "constructivism" or invoking the names of experts such as "according to Vygotsky" are not the same as grounding your research in testable theories, unless you are able to craft a truly testable prediction from them. The hallmark of a testable theory is that it generates testable predictions. For example, the cognitive theory of multimedia learning predicts that students will learn more deeply (as measured by performance on problem-solving transfer tests) from animation and narration than from animation and on-screen text. In short, the research should have the potential to contribute to educational theory.

Third, the research should use a methodology that is appropriate for testing the theory and that is scientifically rigorous. Both quantitative and qualitative methodologies have their respective places, as do experimental and observational studies. However, when the goal is to draw conclusions about causal mechanisms (such as, "Does adding graphics to a text improve student learning?"), then experimental designs are unsurpassed. When the goal is to conduct rigorous research that is convincing to the field, in general, quantitative measures should be included.

Fourth, the centerpiece of any research project is the data. Arguments should be based on the evidence, rather than on slogans or pre-existing expectations. When the goal is to study instructional design, the major dependent variables should be measures of learning outcome—that is, measures of what was learned. In short, we want to know what effect our instructional manipulation has on changes in the student's knowledge. To accomplish this goal we need appropriate data concerning what students know.

Fifth, good research includes logical reasoning that explains the relations among data, theory, and practice. It is also important to acknowledge the limitations of the conclusions that can be drawn. Overall, good research is educationally relevant, theoretically grounded, methodologically appropriate, data based, and logically coherent. It is best to focus on one issue and study it in a variety of ways.

*Q: In a report for the Bertelsmann Foundation, Thomas Reeves said "the esoteric and complex nature of human learning may mean there may be no generalizable best approach to using media and technology in schools. The best we may be able to hope for is creative application and informed practice." Do you agree?*

A: I agree that human learning is complex and I am all for teachers being creative and informed, but I disagree with the underlying premise of this statement that educational psychology has nothing to contribute to improving educational practice. The same statement could be applied to medical practice, but I doubt that you would want to be exposed to medical procedures or drugs that had not been subjected to rigorous experimental research methods. In both cases, research-based principles for practice and research-based theories are useful tools. In spite of claims to the contrary, I believe it is not only possible, but also desirable, to conduct educationally relevant research comparing the learning outcomes of students who learn under different instructional methods. The application of experimental methods to behavioral research is one of the greatest scientific accomplishments of the 20th century. Experimental methodology has a proven track record in psychology. In my opinion, psychology actually has something worthwhile to contribute to education both in terms of research methodology and research-based theory. By the same token, education has contributed to psychology by challenging us to build theories of learning and development that account for academic performance. The result has been the emergence of psychologies of subject matter in which the goal is no longer to create general theories of learning and development but rather to focus on how students develop and learn in specific subject areas. For example, we now have research-based theories of how students learn to read words, to comprehend passages, to write essays, to solve math problems, or to think scientifically. Domain-specific theories of learning and development have been far more successful than classic general theories, producing an advance to psychological theory and educational practice.

*Q: In terms of technology, what research is needed and what theories need testing or development?*

A: We have plenty of untested (and perhaps untestable) theories, frameworks, and models concerning technology. What we need are testable theories—that is, theories that yield testable predictions—and relevant data collected using rigorous scientific methodology. The field of educational technology should continue to develop as a science in which theories are tested against data. We also have plenty of design principles based on the craft knowledge of practitioners, reports of development projects, anecdotes, and testimonials in the form of descriptions of "best-practice." What is missing are testable theories and solid evidence. Finally, we have plenty of essays advocating certain uses of technology—such as using computers to create collaborative environments. However, not enough of them offer a testable theory supporting the proposed use of technology or methodologically sound evidence comparing how students learn with the proposed instructional method versus another. Without a storehouse of relevant research evidence gleaned from sound research studies, mounds of speculations and claims are of little value. The number one question to ask when reading an essay on educational technology is: "Where is the evidence?" If you find yourself reading an the essay about educational technology that is based mainly on speculation, anecdotes, an untestable model, testimonials about an application, or vague references to unspecified evidence, then my advice to you is to move on to an evidence-based paper.

*Q: What is wrong, if anything, with the way we currently design on-line instruction?*

A: In some cases, on-line instruction is based on the craft knowledge of designers, that is, on practical experience. I certainly respect the knowledge and skill of practitioners, but I also believe that our field—educational psychology—has something to contribute to the design of on-line instruction. In particular, I have argued that on-line instruction should be designed in ways that are consistent with what we know about how people learn and with research-based principles. For example, concerning research-based learning theory, we know that people have a limited capacity for processing incoming information, so on-line instruction that presents too much material on the screen at one time (such as multiple graphics) may overload the learner's cognitive system. For example, concerning research-based principles, we know that people learn better when extraneous words, sounds, and pictures are eliminated from on-line instruction. In short, what is wrong with some current on-line instructional programs is that they are not sensitive to how people learn and are not consistent with research-based principles of instructional design.

*Q: There has been much discussion about learning styles, for example by Gregorc and Dunn. Have you found that there are on-line learning styles?*

A: Research on learning styles has had a somewhat disappointing history in psychology and education. Interest in learning styles reached its high point in the 1970s and declined thereafter because of a lack of a strong research base. Based on the current state of the literature on on-line learning, the most important individual differences variable is the prior knowledge of the learner. In general, many of the design principles described in my previous answers apply to low-knowledge learners but not to high-knowledge learners. Kalyuga has proposed the expertise reversal effect in which design principles that help novices may actually harm experts (see Kalyuga's chapter in the forthcoming *Cambridge Handbook of Multimedia Learning*).

My colleagues and I have conducted some research on verbalizer-visualizer learning style within on-line learning environments. Although it is possible to measure individual differences in verbalizer-visualizer style, my associates and I found no evidence to support the idea that verbalizers learn better from on-line lessons that are verbally based whereas visualizers learn better from on-line lessons that are pictorially based.

*Q: What are animated pedagogical agents? How should pedagogical agents be used to assist learning? Do students truly learn more deeply when they interact with animated pedagogical agents*?

A: Animated pedagogical agents are cartoon-like characters that appear on the computer screen during a computer-based lesson or exercise. Through interactions with the learner they can offer suggestions, encouragement, feedback, and needed information. My colleagues and I have found that many of the research-based principles listed in foregoing answers apply to animated pedagogical agents. For example, people learn better when agents talk to them rather than when agents produce on-screen text (i.e., modality principle). Interestingly, my colleagues and I have found no evidence that the agent's gestures affect learning, or even that having the agent's image on the screen is necessary for learning. Thus, instead of asking whether students learn better with or without animated pedagogical agents, a more fruitful question concerns the characteristics of an agent that lead to better learning. For example, in a current set of studies my colleagues and I are examining whether people learn to use a computer-based simulation of assembly lines in a factory when an on-screen agent talks to them in a polite style or a direct style.

*Q: Do games teach*?

A: Like most important questions in psychology, the appropriate answer is: It depends. Games can be designed and used in ways that teach or they can be designed and used in ways that do not teach. A major challenge in using games as instructional devices concerns how to encourage the learner to engage in reflection and other forms of deep cognitive processing while learning.

I have two main cautions concerning using games as instructional tools. First, transfer may be quite limited. For example, in a study by Valerie Sims and I, we found that students who learned how to play the video game, Tetris, showed improvements in mental rotation of Tetris shapes but not mental rotation of other kinds of shapes and not other cognitive skills. Second, students may learn little from fast-paced games unless they engage in reflection activities (such as discussions) after playing the game. Barbara White and her colleagues have shown that students who played physics games in a microworld learned more deeply if they had to engage in discussions of the underlying principles after playing the game.

*Q: To summarize your work, what have you tried to accomplish over the past 10 or 20 years*?

A: Throughout my career in educational psychology, I have had several complementary goals: on the theoretical level, my main goal has been to understand how to help people learn; on the practical level, my main goal has been to develop research-based principles for instructional design; and on the disciplinary level, my main goal has been to explore the value of research evidence in testing educational theories. During the past 10–20 years, I have pursued each of these goals within the context of my research on multimedia learning. First, I have tried to build and empirically test a cognitive theory of multimedia learning, which specifies the cognitive processes involved in meaningful learning from words and pictures. Second, I have tried to derive research-based principles for the design of multimedia learning environments that are consistent with the cognitive theory of multimedia learning and with research evidence. Third, I have tried to contribute to the field by showing how theoretical and practical questions in education can be addressed by collecting relevant data in experimental studies. My sincere hope is that educational psychologists will continue to show how it is possible to base educational decisions on sound research evidence rather than on opinions, speculations, flawed studies, doctrine, or ideology.

*Q: What guidance can you give for helping doctoral students develop into good educational researchers*?

A: In my opinion, the major ingredients in a successful educational researcher are intellectual curiosity, intellectual honesty, and expert knowledge. First, you need to have a driving interest in finding the answers to questions. It all begins with your curiosity, that is, pursuing a question that intensely interests you. Second, you need to have the honesty to go where the evidence takes you, even when the evidence seems to show that your theory is not quite right. In the end, your most essential asset as an educational researcher is your sense of personal integrity. When people begin with an ideological position and seek evidence to prove it, they are not demonstrating integrity. Integrity is reflected in acknowledging when the evidence contradicts your theory, integrity is reflected in not overstating your conclusions even though you would like to, and integrity is reflected in being scrupulously honest in acknowledging shortcomings in your research methods. In short, integrity is based on your faith in science as a vehicle for contributing to human knowledge. Third, you need to make sure that you develop the research skills you need to conduct high-quality research, the professional skills you need to become a member of your research community, and the knowledge of your area you need to become an expert scholar. Scholarship includes knowing what has already been done in your area and how others have conceptualized your area.

Pragmatically, I recommend focusing on one (or possibly two) main themes that characterize your research rather than spreading yourself across too many areas, I recommend creating studies that focus on one clear question rather than many questions, and I recommend publishing high-quality, multi-study articles in the leading journals in your area rather than many minor articles in secondary journals.

*Q: What is the most burning question currently in educational psychology*?

A: There are many burning questions in educational psychology and we have the research tools to address them. Together, these two facts are what make educational psychology such an exciting field. The question that most strongly drives my research concerns the nature of human learning: How can we help people learn in ways that promote transfer, that is, so that they can productively use what they have learned in new situations? This is a classic question in psychology and education that dates back to the beginning of our field. In my opinion, if we could understand how people learn—and in particular, how to help people learn—this would greatly contribute both to psychology and to education.

Learning is at the heart of education. The goal of education is to promote learning, that is, to promote cognitive change in learners. I am interested in the question of how to facilitate this process of cognitive change in learners.