DOES MULTIMEDIA TRULY ENHANCE LEARNING?

MOVING BEYOND THE VISUAL MEDIA BANDWAGON

TOWARD INSTRUCTIONAL EFFECTIVENESS

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ABSTRACT

As our students become increasingly tech-savvy and multiple forms of visual media become the norm in their daily lives, it is only natural that instructional pedagogy would embrace this trend in an endeavor to "speak their language." There seems to exist a prevailing assumption among instructors that video and other forms of multimedia improve the quality of instruction and help students connect with the content. Unfortunately, this is not always so. Until recent years, research in the field of visual media focused primarily on media comparison studies which were informed by sociology and cognitive psychology. Unfortunately, media comparison studies – both in educational context and their mass media predecessors – were plagued with confounding variables and frequently generated mixed results, leaving instructors with uncertain conclusions about how best to utilize multimedia in their instruction. More recent research, such as Richard Mayer's (University of California – Santa Barbara, Psychology), along with A. Paivio's Dual-Coding Theory, are helping academic practitioners learn when and how multimedia actually enhances learning, as well as helping to determine when visual media's effects are negligible or even counterproductive. This paper highlights findings from contemporary educational psychology research regarding the intersection of cognition, instruction, and technology in pedagogical context.

INTRODUCTION

Less than two years ago (2005), the *Journal of Educational Multimedia and Hypermedia* reported on an empirical research experiment designed to test whether video presentations of four types of stories had greater impact on participants' engagement and recall compared to text-only versions of the same stories (Koehler, Yadav, Phillips, & Cavazos-Kottke). The researchers were attempting to counter a claim made by Clark (1983), who concluded that the choice of media has no influence upon learning "any more than the truck that delivers the groceries causes changes in our nutrition" (as cited in Koehler, et al., 2005).

The researchers devised an experiment whereby eighty-four undergraduate students were presented with four types of stories or narratives taken from original video sources: a) a human interest feature story about a robotic dog being used in assisted living facilities to provide artificial companionship, b) an informative and persuasive news story about novel approaches being used by colleges to combat problems with college-age alcohol consumption, c) an artistic piece (a poem) about a relationship that ended with sorrow and regret, and d) a lecture where Dr. Marvin Minsky briefly describes his theory of language (Koehler, et al., 2005). The print versions of the first two were formatted to have the look and feel of a newspiece from the same network news station that had prepared the story, and the text versions of the latter two were designed to be as equivalent as possible to the original video version while still reading as text (Koehler, et al., 2005).

Web pages were utilized for the display of the stories, administration of the survey, and collection of the data. The researchers used a variety of Likert-type and semantic differential scales to determine the level of engagement of the participant(s), measure the extent of change in the participants' opinions about the subject matter, and open-ended questions about story-specific information to test recall (pp. 254-255).

The researchers found that video influenced the participants' responses – particularly in areas of engagement, affective change, and impressions of quality – in ways that reading a text-alone piece does not; however, *in traditional measures of cognitive achievement such as information recall and summarization of main ideas, there was relatively little variance between* *the text and video formats* (p. 269). In essence, the use of video influenced how students perceived and felt about the presentations but it did not actually improve learning.

This finding has significant educational implications, suggesting that ***how*** video is used is more important than ***whether*** video is used. The researchers concluded that video can be an effective tool for: (a) enhancing affect or mood or tone when such is not readily apparent in the text, (b) engaging interest by supplementing the text or audio channels with additional cues, and (c) increasing perceptions of credibility, but that video alone does not automatically constitute a more effective delivery vehicle for information.

For developers of classroom multimedia, whether they be faculty or instructional designers, this discovery has startling ramifications. As a result of this article, this author set out to discover if the finding was incidental and isolated or whether other research supported their conclusion. Contrary to expectations, the evidence reveals that educational psychology has grappled with this issue over the last several decades and that the research consistently fails to support the commonly-held assumption that multimedia use actually enhances learning (Mayer, 2001, pp. 70-72).

This paper will provide a brief overview of the historical and theoretical foundations of multimedia use, beginning with early psychological studies regarding media effectiveness and devoting considerable attention to the challenges inherent with media comparison studies. Also covered will be the theoretical foundations of multimedia learning, particularly the emergence of cognitive psychology. Two vital theoretical foundations to discuss will be the concept of cognitive load, as explained by Sweller (2005a) and the dual coding theory espoused by Allan Paivio (1990). Finally, this paper will introduce the Cognitive Theory of Multimedia Learning advocated by Richard E. Mayer, professor of psychology at the University of California – Santa

Barbara, whose research interests are in the areas of educational and cognitive psychology, particularly "the intersection of cognition, instruction, and technology" (University of California – Santa Barbara [UCSB], ¶ 1).

From Mayer's research, which encompasses over a hundred experiments analyzing the effectiveness of various uses of multimedia, this paper will present six well-established principles of multimedia learning which research continues to support. They include: (a) the multimedia principle, (b) the split-attention principle, (c) the temporal contiguity principle, (d) the modality principle, (e) the redundancy principle, and (f) the coherence principle. After considering the premise and theoretical foundations of each principle, this paper will examine some examples as well as some classroom applications. The intent of this paper will be to derive some research-based principles for more effective use of visual media in the classroom.

HISTORICAL AND THEORETICAL FOUNDATIONS

Early Psychological Studies on Media Effectiveness

The use of media for instruction is not new. Psychological studies of the learning value of video (films) were conducted as early as 1919, when researchers Lashley and Watson (1922) analyzed the adaptations of World War I training films for civilian use (as cited in Heinich, Molenda, & Russell, 1993, p. 24). A large-scale study (Freeman, 1924) of the instructional use of video (film) was also conducted in the Chicago public schools a few years later (as cited in Heinich, et al., p. 24).

By the late 1940s, the U.S. military (Hovland, Lumsdaine, & Sheffield, 1949, p. v) had commissioned the Experimental Section of the Research Branch of the Army's Information and Education Division "to make experimental evaluations of the effectiveness of various programs of the Information and Education Division" (as cited in Baran & Davis, 2003, p. 140). These studies of the persuasive effectiveness of the War Department's "Why We Fight" orientation films were conducted by renowned psychologist Carl I. Hovland, whose background in behaviorism and learning theory gave him a unique advantage in identifying the essential elements of attitude change (Baran & Davis, 2003, p. 141). The Experimental Section tried various combinations of delivery methods and persuasive argumentation strategies, eventually concluding that attitude change was very complex, necessitating continued and expanded research. As a result, Hovland established the Communication Research Program at Yale University, funded by the Rockefeller Foundation, to explore in-depth "the variables Hovland considered central to attitude change: the communicator, the content of the communication, and the audience" (Baran & Davis, 2003, p. 142).

Through the research of the Yale Group, a whole new era of communication research was spawned which made heavy use of media comparison studies and strongly influenced the fields of psychology and media effects research, giving rise to such names as Paul Lazarsfeld (1955), Leon Festinger (1967) and his theory of cognitive dissonance, Melvin DeFleur (1970), Thomas Kuhn (1970) and his groundbreaking *The Structure of Scientific Revolutions*, and of course, Carl Hovland (as cited in Baran & Davis, 2003, pp. 128, 133-136, & 139-153).

Media Comparison Studies

By 1947, the U.S. Army was conducting research with the hypothesis that film-based instruction was more effective at accomplishing desired learning outcomes than traditional classroom and paper-based versions (Clark & Mayer, 2003). One particular experiment involved three versions of instruction: (a) a film version featuring a narrated demonstration of how to read a micrometer, (b) a classroom presentation where the instructor demonstrated reading of a micrometer with the equipment and still slide pictures, and (c) a paper self-study version with pictures and arrows to indicate movement. All three versions utilized the identical lesson script. The subject learners were randomly assigned to one of the instruction versions and tested afterwards to see if they could read the micrometer. Hall & Cushing (1947) reported in the *Journal of Psychology* that there were *no differences in learning* among the groups (as cited in Clark & Mayer, 2003, 20).

This is quite similar to the findings of Hovland and his colleagues: “Prevailing notions about the power of propaganda implied that the researchers would find dramatic shifts in attitude as a result of viewing the films” (Baran & Davis, 2003, p. 141), but typically, the films only served to reinforce existing attitudes and conversions were rare (141). Although their focus was persuasion research, the educational ramifications were strong.

The Army’s investigation of film-based instruction was an example of what came to be known as media comparison studies, experiments in which the effectiveness of communication (or instruction) from one form of media is compared to that of another form – often the traditional format such as lecture or book/paper. Over the last several decades, literally hundreds of media comparison studies were conducted (Clark, 1994, Dillon & Gabbard, 1998), “yet with rare exception they have observed the same thing: no differences in learning” (as cited in Mayer, 2005). Consequently, media comparison studies have largely been disbanded in favor of cognitive approaches offering more empirical merit. As Mayer (2001) explains, media comparison research “can be criticized on empirical, methodological, conceptual, and theoretical grounds” (70).

From an **empirical** perspective, media comparison studies have had a disappointing history with inconclusive empirical results (Clark & Salomon, 1986; Mayer, 1997; as cited in Mayer, 2001, p. 70). Further, Heinich, et al. (1993) observe that "analysis of the content treated in these studies reveals…a bias toward cognitive objectives, as opposed to attitudinal, interpersonal, or motor skill objectives and assessment of the results utilized paper and pencil verbally-oriented tests (25). Thus, it is not surprising that lecture and textbook treatments, which are primarily verbal approaches, using verbal assessment techniques, scored so comparably to the media treatments (25). These studies did not effectively assess the visual aspect of learning. Fundamentally, the question has to be asked, "Are we comparing apples and oranges?" Or as Heinich, et al. (2003) put it, "it is like trying to compare 'can-of-worms A' with 'can-of-worms B" (25).

On **methodological** grounds, there are serious concerns as well. The earliest studies – particularly those from cognitive and social psychology – suffered from confounding variables. Simply put, too many other factors were involved which could at least partially explain the results. Mayer (2001) provides an example of a comparison made between learning from two types of media: the tone of voice of the speaker and the way words were stressed in the narration varied between the computer-based presentation and the way printed text was laid out and formatted on the page in the print version (70). However, when efforts were made to control for all potentially confounding variables so that the only variable was the delivery system, this effectively mitigated some of the potential power of multimedia (Heinich, et al., 2003, 24-25). Thus the lab standards of purity for research design compromised the very effects that researchers were trying to confirm…"the more successful the researchers were in controlling the conditions of the media treatment, the less it resembled what would be normal good practice in media use" (Heinich, et al., 2003, 25).

Conceptually, a third problem with media comparison research is that learning depends on the quality of the instruction rather than the media utilized (Mayer, 2001, pp. 70-71). As Mayer (2001) explains, "It is possible to design a textbook so that students have great difficulty in understanding the material, and it is possible to design a textbook so that students can understand the presented material more easily. Similarly, it is possible to design a computer-based presentation in ways that either hinder or promote meaningful learning." Mayer's (2001) research has demonstrated that the same factors that improve student understanding in a book-based environment also promote student understanding in a computer-based environment" (71).

Fourth, the **theoretical foundations** of media comparison research are suspect. Research on media effects is based on an information-delivery view of learning, one where the media utilized is viewed as a delivery system for conveying information from the instructor to the learner (Mayer, 2001, p. 71). Richard Mayer (2001) considers this "an outmoded conception of learning that conflicts with the Cognitive Theory of Multimedia Learning and with several key ideas in cognitive psychology, including the ideas of dual-channel processing, limited capacity, and active processing" (71). Asking "Which form of media delivery is more effective" presumes an information-delivery model rather than a "knowledge-construction" view. As prominent constructivist Jonassen & Reeves (1996) explains, "Whether one sides with those who believe that media have little or no effects on learning or those who promote its unique instructional effectiveness, such arguments are limited by narrow definitions of media as conveyors of information… [This perspective is] inherently flawed because it fails to recognize learners as active constructors of knowledge" (as cited in Mayer, 2001, p. 71).

As Clark & Mayer (2003) summarize, "What we have learned from all the media comparison research is that it's not the medium, but rather the instructional methods that cause learning. When the instructional methods remain essentially the same, so does the learning, no matter how the instruction is delivered" (21).

THEORETICAL FOUNDATIONS OF MULTIMEDIA LEARNING

A significant benefit of learning technology is that it has the potential to reach larger audiences than previously imagined and that some interactive and e-learning derivatives of it place the learner in control of the learning experience, potentially tailoring the educational experience to the unique circumstances and needs of every learner (Finnis, Section 2, ¶ 1 & 3). However, the more that instruction is conveyed visually, the greater the imperative to pay attention to the ways in which learners develop their mental representations.

Clark & Mayer (2003) observe that "each new wave of instructional technology (starting with film in the 1920s) spawned optimistic predictions of massive improvements in learning" (20). However the results have consistently fallen far short of that optimism. The prevailing assumption that media improves learning is simply not supported by the research. As Clark & Mayer (2003) explain, "After fifty years of research attempting to demonstrate that the latest media are better, the outcomes have not supported that hypothesis" (21).

So why would a media specialist make such a confession? Are people who develop and facilitate instructional media out of a job? Should higher education give up on classroom multimedia. Not at all! What media specialists work with are the tools to enable effective instruction, but the instruction itself rests in the hands of the instructors. Thus, it is not the use of media which necessarily enhances learning; it is the way in which media is used which makes the difference. Instruction can certainly be conveyed effectively through the use of visual media, but pedagogy – instructional methodology – is what determines whether the tool is effective or not. Having the right tools on hand helps, but the media is only effective if the instructional methodology supports the medium.

Emergence of Cognitive Psychology

While it is not the intent of this paper to review all of the literature regarding cognitive psychology, a brief survey of the contributory landscape may help with dialogue. Research on learning began to shift in the 1950s from an emphasis on stimulus design (e.g., communication) to the learner's response to stimuli (Heinich, et al., 13). Chief among these was Harvard psychologist B.F. Skinner, a behaviorist who was interested particularly in the learning of new skills in contrast to reflexive behavior such as demonstrated by Pavlov's famous salivating dog (Heinich, et al., 13; Alessi & Trollip, 17). B. F. Skinner believed that learning could be "understood, explained, and predicted entirely on the basis of observable events," in particular, the learner's behavior in reaction to environmental antecedents and consequences (Reiser & Dempsey, 2007).

Skinner's conclusion that behavior could be "shaped" by reinforcement or "conditioning," which he conducted with pigeons but theorized about regarding humans, became known as reinforcement theory and was the basis for much of instructional design in that era (Heinich, et al., 13; Alessi & Trollip, 17). As behaviorism's dominance began to wane in the last third of the twentieth century, cognitive psychology has taken its place (Alessi & Trollip, 19). According to Alessi & Trollip in their synthesizing book *Multimedia for Learning*, "Cognitive psychology places emphasis on unobservable constructs, such as the mind, memory, attitudes, motivation, thinking, reflection, and other presumed internal processes" (19).

A prominent educational outgrowth of the behavioral perspective was the emergence of *programmed instruction*, whereby an instructor takes the learner though a series of programmed steps leading toward desired performance outcomes; behavioral objectives, programmed instruction, personalized systems of instruction, and learning activity packages are some of the inheritance of this theory which dominated the next several decades. Although its influence has waned, the movement it spawned remains active, particularly with "systems" approaches to instructional design, such as computer-assisted instruction or CAI (Heinich, et al., 13).

In 1968, Atkinson and Shriffrin "proposed a multistage, multistore theory of memory that is generally regarded as the basis for information processing theory" (38). The three memory stores included were sensory, short-term, and long-term memory (38). Information processing theory, like behaviorism, recognizes the essential role the environment plays in learning, but differs in its assumption that internal processes within the learner explain much of the learning (as cited in Reiser & Dempsey, 2007, p. 38). Information processing theory forms the basis of cognitive theories of instruction, particularly the Cognitive Theory of Multimedia Learning which this paper will explore.

Other theoretical perspectives, such as *schema theory* – where knowledge is represented in long-term memory in organizational packets of information called schemata (Reiser & Dempsey, 2007, p. 39), and *situated learning theory* (a.k.a. "situated cognition") – where social and cultural determinants are more important than individual psychology (Reiser & Dempsey, 2007, p.40), and *constructivism* – where the learner is actively involved in negotiating and organizing the educational experience, play an important role in instructional design, but are not central to cognitive approaches to learning. However, cognitive load theory is a vital theoretical background which is assumed in the Cognitive Theory of Multimedia Learning.

Cognitive Load Theory

Sweller (2005a) argues that "Good instructional design is driven by our knowledge of human cognitive structures and the manner in which those structures are organized into a cognitive architecture" (as cited in Mayer, 19). As a result, cognitive load theory has emerged as a means of integrating knowledge of human cognitive structures with good instructional design principles (Sweller, 2005a).

Cognitive load theory is based on the premise that people have a limited capacity for working memory (Miller, 1956) and an enormous long-term memory (Chase & Simon, 1973) (as cited in Koroghlanian & Klein, 2004). The origins of the theory rest with DeGroot (1965), who analyzed how chess grand masters were consistently able to defeat less able players with relatively little cognitive effort. The distinguishing factor proved to be that chess masters had relegated a significant number of board configurations and scenarios to long-term memory and thus knew precisely how to respond in any given situation (as cited in Sweller, 2005a, p. 20). After being shown a board configuration briefly, chess grand masters were able to replace most of the pieces from memory while less able players could only replace a few pieces. Later research by Chase & Simon (1973) replicated the result but not with random configurations; the results only occurred when the board configurations came from real games (as cited in Sweller, 2005a), leading investigators to conclude that information stored in long-term memory was what constituted "expertise" (Sweller, 2005a, p. 20). In terms of problem-solving, "skill is determined by information in long-term memory concerning problem states and the best move associated with each state" (Sweller, 2005a, p. 20).

However, working memory is limited in capacity. Miller (1956) determined that working memory can only hold about seven elements of information and can process – in the sense of combining, contrasting, or manipulating – no more than about 2-4 elements at a time (as cited in Sweller, 2005a, p. 21). Thus both the capacity of working memory for dealing with novel information and the duration are severely constrained. Peterson & Peterson (1959) found that, without rehearsal, "almost all of the contents of working memory are lost within about 20 seconds" (as cited in Sweller, 2005a, p. 22). Rehearsal and application are the means in which the contents of working memory are transferred to longer term memory stores.

Hopefully the instructional implications of this are clear: "a major function of instruction is to overcome the inevitable limitations of working memory" (Sweller, 2005a, p. 23). According to Koroghlanian & Klein (2004), "Cognitive load theorists seek techniques to increase working memory by reducing cognitive load, which in turn should result in improved instructional design, learning efficiency, and effectiveness" (25-26). Cognitive load theory is one of several premises undergirding Mayer's (2005) Cognitive Theory of Multimedia Learning (Mayer, p. 33). A second assumption is that humans possess separate channels for processing visual and auditory information, a well-documented school of thought which has come to be known as dual-channel or dual coding theory (Pomales-Garcia & Liu, ¶ 18).

Dual Coding Theory

The dual-channel assumption in Mayer's (2005) Cognitive Theory of Multimedia Learning posits that humans possess separate information processing channels: one for visual representations and one for auditory representations (Mayer, p. 33). According to Richard Mayer (2005), the concept of separate information processing channels has a long history in cognitive psychology and currently is most closely associated with Paivio's dual-coding theory (Clark & Paivio, 1991; Paivio, 1986) and Baddeley's model of working memory (Baddeley, 1986, 1999) (as cited in Mayer, p. 34). According to Emporia State University IDT instructor Marcus Childress, Paivio's theory of memory and cognition "remains to be the most widely accepted theory for the recall of concrete nouns" (Childress, 15).

Dual coding theory was introduced by Allan Paivio (1986, 1990) in his influential book *Mental Representations: A Dual Coding Approach*. Dual-coding theory rests upon the assumption that humans possess two distinct systems for symbolic representation in cognition: one which specializes in verbal information and the other which specializes in nonverbal information (Childress, 15, citing Paivio & Lambert, 1981). Of particular interest for multimedia learning is the ability of the learner to not only build both verbal and visual modes of mental representation but also to establish meaningful connections between them (Mayer & Anderson, 1999), as illustrated in the following diagram showing Paivio's dual-coding model as adapted by Richard Mayer (2001):

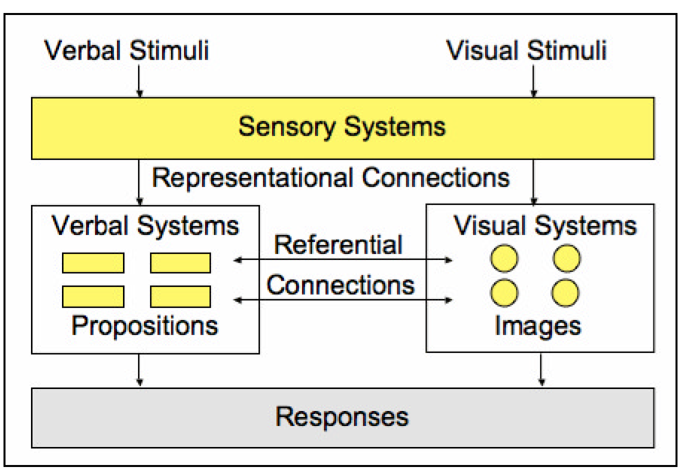

Figure 1. The dual-coding model for cognitive processing of animation and speech.
Adapted by Richard S. Mayer (2001) from *Mental Representations: A Dual Coding Approach*, p. 67 by A. Paivio (1990).

Mayer (2005) elaborates further, “There are two ways of conceptualizing the differences between the two channels – one based on presentation modes and the other based on sensory modalities” (34). With the *presentation mode* approach, the conceptualization which is most consistent with Paivio’s (1986) theory of dual coding, one channel processes presented stimuli which are verbal – such as spoken or printed words – and the other channel processes presented stimuli which are pictorial or nonverbal, such as pictures, video, animations, and background sounds (as cited in Mayer, 2005, p. 34). With the sensory modalities approach, the conceptualization most consistent with Baddeley’s (1986, 1999) distinction between the visuo-spatial sketchpad and the phonological (or articulatory) loop, the emphasis is on which of the senses is used: the **eyes** (pictures, video, animations, or printed words) or the **ears** (spoken words or background sounds) (Mayer, 2005, p. 34). Mayer (2005) opts for a compromise between the two approaches, noting that further research is needed to clarify the nature of those differences (pp. 34-35).

In short, “In its broadest sense, Paivio’s theory assumes that there are relationships between symbolic systems – verbal and nonverbal representation – and sensorimotor systems – such as visual, auditory, haptic, taste, and smell” (Childress, 15, citing Paivio, 1986) and “[e]ach of these systems and subsystems comprise an integrated whole, while at the same time, they are separate integrated parts which can function independently” (Childress, 15, citing Paivio & Lambert, 1981). The essence of dual coding theory is the processing of mental representations, or how one mentally assimilates new information. As Childress explains:

> “A single word or picture can trigger many different referents in the verbal and visual systems. When a person sees the word "table" for example, "table," through referential processing, triggers visual referents in the visual system, which in turn activate the process of association, resulting in representations dining tables, picnic tables, card tables, etc.. Likewise, when a person sees a

> picture of a table, that picture triggers the word "table" in the verbal system. This referential activity also activates associative processing within the verbal system, resulting in representations such as the words dining table, picnic table, and card table. Thus, verbal stimuli precipitate visual representations, and visual stimuli set off verbal representations” (18).

In conjunction with cognitive load theory, dual coding theory forms a substantial basis for Mayer’s Cognitive Theory of Multimedia Learning.

THE COGNITIVE THEORY OF MULTIMEDIA LEARNING

This paper focuses heavily on the research and contributions of Richard E. Mayer, who is professor of psychology at the University of California, Santa Barbara, where he has served since 1975. Mayer’s research interests are in the areas of educational and cognitive psychology, and his current research “involves the intersection of cognition, instruction, and technology, with a special emphasis on multimedia learning and problem solving” (University of California – Santa Barbara [UCSB], ¶ 1).

Having served as past-President of the Division of Educational Psychology for the American Psychological Association, as former editor of the *Educational Psychologist* and former co-editor of *Instructional Science*, as well as former department chair of Psychology at the University of California – Santa Barbara, Mayer is uniquely qualified as an authority in this field. Additionally, he is a prolific writer, having authored 18 books so far and more than 250 articles and chapters, including his most recent works *Learning and Instruction* (2003), *Multimedia Learning* (2001), and the *Cambridge Handbook of Multimedia Learning* (2005), which he edited (as cited in UCSB, 2006a, ¶ 1). The latter two works were used extensively in this paper.

Particularly impressive in the preparation of this paper was the discovery that almost every highly-recommended book in this field had been authored, co-authored, or contributed to by Mayer, and nearly every journal article this author reviewed had either been contributed to by Mayer or cited at least 4-5 of Mayer's works extensively. Mayer's webpage at UCSB explains that his research "is motivated by the question, 'How can we help people learn in ways that allow them to use what they have learned to solve new problems that they have never seen before?'" (UCSB, 2006b, ¶ 3). Of particular interest to this campus, Mayer's current research, funded by the National Science Foundation and the Office of Naval Research, explores how individual differences in verbal and visual learning styles influences learning from online courses and how people learn scientific reasoning skills using an online digital library (UCSB, 226b, ¶ 4).

Over the last decade, Richard Mayer and his colleagues have conducted over one hundred experimental tests regarding multimedia learning (UCSB, 2006b, ¶ 3). Building on cognitive science theories of how people learn – and through his extensive research – Mayer has developed a theory of multimedia learning and online learning environments which he terms "the Cognitive Theory of Multimedia Learning" (UCSB, 2006b, ¶ 3).

Although he continues to expand and publish research on principles of multimedia – particularly in the areas of effective online learning environments, there are six well-established principles of multimedia learning which we will focus on for the purposes of this paper. These basic principles include: (a) the multimedia principle, (b) the split-attention principle, (c) the temporal contiguity principle, (d) the modality principle, (e) the redundancy principle, and (f) the coherence principle. All six principles are well-established and well-documented, are solidly grounded in theory, and have been proven repeatedly in empirical research.

The Multimedia Principle

As defined by Mayer (2001), multimedia is the presentation of material using both words and pictures; it is one of the most common terms used in references to educational technology and distance learning (as cited in Pomales-Garcia & Liu, ¶ 17). The multimedia principle asserts that “students learn better from words and pictures than from words alone” (Mayer, 2001, p. 63). However, it must be noted that this does not refer to graphics used as decorative illustrations but to graphics used as explanatory illustrations (Clark & Mayer, 2003, p. 55).

In contrast to the information-delivery view which sees teaching as consisting of information presentation and where learning consists merely of information acquisition, the cognitive theory views learning “as a process of active sense-making” and teaching as “an attempt to foster appropriate cognitive processing in the learner” (Clark & Mayer, 2003, p. 60). That goal is best achieved by using graphics which are meaningful and illustrative in conjunction with words.

Example. Examples of the multimedia principle are numerous. With the advent of desktop publishing programs and the graphically illustrative capabilities of Microsoft Word and PowerPoint, adding graphics to a multimedia presentation is relatively easy. The challenge is finding useful graphics that convey meaning and illustrate effectively, not simply the myriad of clip art images which serve no instructive purpose (and which can actually be a hindrance to learning, as will be discussed in another principle). An example from some of the original research used an animation of how a bicycle pump works to support the textual &/or verbal description (Mayer, 2001a): “As the rod is pulled out, air passes through the piston and fills the area between the piston and the outlet valve. As the rod is pushed in, the inlet valve closes and the piston forces air through the outlet valve” (as cited in Clark & Mayer, 2003, p. 61).

Scientific and mechanical process in particular greatly benefit from illustrative graphics and animations.

Theoretical rationale. The theoretical rationale behind the multimedia principle is that when both words and pictures are presented, learners are able to establish verbal and pictorial mental models and build effective connections between the two. When words alone are presented, learners are able to build a verbal mental model but are less likely to establish a visual model and make appropriate connections (Mayer, 2001, p. 63).

Empirical basis. In research conducted by Richard Mayer and his colleagues on the multimedia principle (Mayer, 1989; Mayer & Gallini, 1990; Mayer & Anderson, 1991; Mayer & Anderson, 1992; and Mayer, Bove, Bryman, Mars, & Tapangco, 1996), learners who received text and illustrations – or narration and animation – performed better on retention tests in six of nine tests conducted than learners whose instruction consisted only of text or narration by itself (as cited in Mayer, 2001, p. 63). For transfer-of-learning tests, learners whose instruction included text and illustrations – or narration and animation – performed better in nine of nine tests conducted compared with learners whose instruction consisted of text or narration alone (Mayer, 2001, p. 63).

Classroom Ramifications. Instructors should actively seek graphics which convey meaning and illustrate effectively whenever possible. In classroom applications – and especially in e-learning and online environments, such graphics can teach content types, serve as topic organizers or lesson interfaces, or show relationships (Clark & Mayer, 2003, pp. 56-59). In the context of e-learning, Clark & Mayer (2003) provide a list of good uses of graphics to accompany text: (a) graphics are used for presenting instructional content and are relevant rather than decorative; (b) representative graphics are used to illustrate concrete facts, concepts, and their parts; (c) animation is used to illustrate processes, procedures, and principles; (d) organizational graphics are used to show relationships between and among ideas and lesson topics, (e) interpretive illustrations such as graphs are used to convey relationships between variables, and (f) graphics are used as a lesson interface (64). Most of these uses would apply to face-to-face presentation as well as e-learning scenarios.

The Split-Attention Principle

Split attention in instruction occurs when several sources of information requiring cognitive processing are separated from each other. Researchers (Ayres & Sweller) have confirmed that the need to mentally integrate the multiple sources of information substantially increases cognitive load, thereby hindering the overall learning accomplished (2005, p. 135).

Example. A good example of this is the presentation of a worked example in geometry, where the illustration which the sample pertains to is followed by a textual explanation of the problem (Ayres & Sweller, 2005). To successfully comprehend the worked example, learners must mentally integrate the illustration and its angles being calculated with the textual analysis of the problem and the solution it describes. The cognitive load produced by this example substantially impedes the rate of learning. However, by integrating the textual explanations with the illustration, learning is effectively increased (Ayres & Sweller, 2005). With an integrated version, learners "do not have to search the screen or page to find a graphic that corresponds to a printed sentence; therefore they can devote their cognitive resources to the processes of active learning, including building connections between words and pictures" (Mayer, 2001, p. 87).

Theoretical rationale. Initial research regarding this split-attention effect was conducted by Tarmizi and Sweller (1988) analyzing the effectiveness of worked examples on learning geometry as has just been discussed (as cited in Ayres & Sweller, 2005, p. 137). Subsequent research by Chandler & Sweller (1991) should be of particular interest to technology faculty. In an nonmathematical setting, Chandler & Sweller (1991) found that split attention scenarios were common in instructional materials prepared for electrical apprentices: “For example, in learning about the installation of electrical wiring, instructions invariably included diagrams of electrical circuits separated from written explanations on how the circuits worked (as cited in Ayres & Sweller, 2005). By integrating texts and diagrams, Chandler & Sweller demonstrated that the split-attention effect could be avoided, resulting in superior performance by the integrated design group (as cited in Ayres & Sweller, 2005). However, this effect is only observed when multiple sources of information must be integrated to be understood; when the multiple sources contain the same information, integrating them is not beneficial.

Empirical basis. In research conducted by Richard Mayer and his colleagues on the split-attention effect (Mayer, 1989; Mayer, Steinhoff, Bower, & Mars, 1995; and Moreno & Mayer, 1999), learners performed better on ***retention*** tests in both tests conducted when corresponding text and illustrations were placed in proximity to each other than when they were separated. On ***transfer*** tests, learners performed better in all five tests conducted when the corresponding text and illustrations were in proximity rather than separated (as cited in Mayer, 2001, p. 81).

Classroom ramifications. When preparing visuals and multimedia for classroom instruction, instructors should ensure that disparate sources of information which must be successfully integrated cognitively for the learner to understand the material are presented in an integrated format (Ayres & Sweller, 2005, p. 136). Further, in classroom presentations, instructors may wish to consolidate material into one presentation format or another – i.e., all on

PowerPoint-managed slides or all on the whiteboard, rather than separate analytical components if the topic requires integration of the resources to be drawn or displayed.

The Temporal Contiguity Principle

Related to this split-attention effect is the temporal contiguity principle, first identified by Richard Mayer. Split-attention refers to physical proximity and involves decisions regarding the economics of space; temporal contiguity pertains to the proximity in time of narration and animation. As Mayer (2001) explains, "Students learn better when corresponding words and pictures are presented simultaneously rather than successively" (p. 96).

Example. One example Mayer (2001) uses involves a sixteen-stage textual description of the process of lightning formation. Temporal contiguity problems occur when either the entire narration is presented first, prior to a supporting animation, or when an animation is displayed prior to the verbal description. This "successive" presentation results in a separation in time between the corresponding words and pictures (98). A better approach would be to display the narration and animation in close proximity time-wise, so that "when the narration describes a particular action in words, the animation depicts the same action visually at the same time" (99). This "simultaneous" presentation resolves the temporal contiguity issue and thus results in greater learning, particularly on transferability to other problems (99).

When words and pictures are integrated, learners "can hold them together in their working memories and therefore make meaningful connections between them" (Clark & Mayer, 2003, 77), which assists in making sense of the lesson. In e-learning environments, use of links to supporting material – rather than directly placing the most succinct and relevant material along with the lesson – can exemplify temporal contiguity problems. Technologies such as JavaScript and Flash, which allow progressive unveiling and animation of illustrations along with accompanying textual explanations, resolve the temporal contiguity challenges.

Theoretical rationale. The theoretical rationale of the temporal contiguity effect is explained well by Mayer: “When corresponding portions of narration and animation are presented at the same time, the learner is more likely to be able to hold mental representations of both in working memory at the same time, and thus the learner is more likely to be able to build mental connections between verbal and visual representations” (2001). Likewise, “when corresponding portions of narration and animation are separated in time, the learner is less likely to be able to hold mental representations of both in working memory at the same time and thus less likely to be able to build mental connections between verbal and visual representations” (2001).

Empirical basis. In research conducted by Richard Mayer and his colleagues on the temporal contiguity effect (Mayer & Anderson, 1991; Mayer & Anderson, 1992; Mayer, Moreno, Boire, & Vagge, 1999; Mayer & Sims, 1994; and Moreno & Mayer, 1999), learners performed better on ***retention*** tests when corresponding portions of animation and narration were presented simultaneously instead of successively. This was true in three of five experiments. On ***transfer*** tests, learners performed better in eight of the eight tests conducted when corresponding portions of animation and narration were presented simultaneously rather than successively. However, there was not a strong temporal contiguity effect when the presentation segments were very short. This held true for both retention and transfer in three out of three tests conducted (as cited in Mayer, 2001, p. 96).

Classroom ramifications. Rather than present a topic and then follow it in succession with a graphic explaining the narration, instructors should consider presenting both on the same slide, transparency, or video overlay. Although space economy would seem to dictate that display of text as one image or slide, preceded by a visual demonstrating the text just displayed, the research consistently affirms that this method results in significantly lower retention and transfer rates than when the graphics which correspond to the text are displayed together. Thus it would be better to have seven slides progressively unveiling the explanatory text, with seven frames of the accompanying graphic being "built" a slide at a time alongside the narrative it illustrates, than to have six slides of step-by-step narration with a seventh slide of the composite explanatory image.

The Modality Principle

Research indicates that "the capacity limitations of working memory are a major impediment when students are required to learn new material" and that these limitations are for the most part inflexible (Low & Sweller, 2005). However, in specific scenarios it is possible to present part of the information visually and a portion of the information in auditory mode. Doing so appears to effectively expand working memory capacity and thereby reduce the effects of excessive cognitive load (Low & Sweller, 2005, p. 147).

According to Richard Mayer (2001), "[S]tudents learn better when words in a multimedia message are presented as spoken text rather than printed text" (p. 134). This is in contrast to the information-delivery theory, which assumes that "multimedia learning is improved by presenting information to learners via as many routes as possible" (Mayer, 2001, p. 137).

Applications of information-delivery theory appear to be fairly commonplace in education, but the research does not support it. As Mayer (2001) explains, information-delivery "is based on an outmoded conception of learning as information acquisition in which learning involves taking presented information and placing it inside one's memory;" in this view, "learning occurs when information is presented by the instructor and received by the student" (Mayer, 2001, pp. 137-138). If dual-coding theory is correct – and the research thus far consistently affirms it – information presented in a mixed mode (partly visual and partly auditory) is more effective than when the same information is presented in a single mode (either visual or auditory alone)

Example. Mayer's research has included lessons involving scientific explanations of how car brakes work, how a bicycle pump works, or how lightning storms develop (2001, p. 135). In one of many experiments, Mayer & Anderson (1999) used an animated depiction of how a bicycle tire pump works, along with words from an accompanying sound track the authors adapted from an encyclopedia article (484). The researchers simulated three different conditions by a) presenting the sound track simultaneously with the animation, b) playing the sound track *before* the animation, c) playing the sound track alone, and d) showing the animation alone (484-485). Student responses to both the information-recall questions and problem-solving transferability questions not only confirmed the dual-coding hypothesis but also affirmed that using both visual and auditory channels to communicate the instructional material resulted in better recall *and* transfer (489-490).

Theoretical Rationale. The theoretical rationale behind this *modality effect* relies on dual coding theory. According to Mayer, "People have two separate information-processing channels – one for visual/pictorial processing and one for auditory/verbal processing" (2001, p. 139). When both pictures and words are displayed in multimedia, only the visual channel is utilized and it can easily become overloaded; when the narration is presented auditorily, it can be processed by the auditory/verbal channel, allowing the visual/pictorial channel more cognitive resources to process the graphical content (Mayer, 2001, p. 134).

Empirical Basis. In research conducted by Richard Mayer and his colleagues on the modality effect (Mayer & Moreno, 1998; Mousavi, Low, & Sweller, 1995; and Moreno & Mayer, 1999), learners who received animation and narration performed better in four out of four tests than did learners who received animation and on-screen text. This finding was true for both ***retention*** and ***transfer*** (Mayer, 2001, p. 134).

The retention percentage improvement for students who received the animation with narration – versus those who received animation with text – was consistent and moderately strong, ranging from a 17% to 47% improvement in the four tests conducted (Mayer, 2001, p. 142). On average, students who received narration along with the animation remembered 30% more of the important material than those who received on-screen text along with the animation. For problem-solving transfer, students performed poorly when exposed to narrations involving on-screen text. By contrast, animation-with-narration learners reflected gains of between 41% and 114% in the four experiments conducted; e.g., students who were provided the animation with narration generated on average 80% more creative solutions on the transfer test than did those who received the animation with text.

Classroom Ramifications. This finding is particularly relevant for technology curricula, where effective instruction requires both visual and verbal explanations of scientific material and its applications, whether that be an illustration of wave generation or an analysis of the effect of capacitors on electronic circuits. Ideally, dynamic methods of interaction – such as hands-on practice with wave generators, circuit boards, and programmable logic controllers – would be used to induce active learning in these scenarios.

However, when static delivery methods (such as PowerPoint, video clips, or computer animations) are used, this modality principle must be considered. When narration accompanies an animation or video, avoid providing the text on the screen. Presenting some information in visual mode and other information in auditory mode can expand working memory capacity and so reduce the effects of an excessive cognitive load. If presenting a step-by-step flow of action, either represent it in stages with the accompanying graphic appearing in successive builds as the text explains it – to take advantage of temporal contiguity – or use an animation or video to illustrate, but narrate it instead of displaying text along with the visual.

The Redundancy Principle

The redundancy principle refers to the idea that instructions presenting duplicate information in different forms or with unnecessary explanatory material actually interferes with rather than facilitates learning (Mayer, 2005, p. 167). "Students learn better from animation and narration than from animation, narration, and text" (Mayer, 2001, p. 147). Coordinating redundant information with essential information increases working memory load, which interferes with the transfer of information to long-term memory.

Example. A common scenario demonstrating this redundancy effect is when a presenter reads or quotes the text directly off of the PowerPoint slide or advances to a text-heavy slide yet continues to try to maintain audience attention. This obvious redundancy often leads to audience members (or "learners") "tuning out" rather than paying full attention, or becoming wrapped up cognitively in either the verbal presentation or the textual material and miss the other.

Theoretical Rationale. The redundancy principle is often counterintuitive; many people assume that presenting the same information in multiple forms is at the least neutral in effect and at best, advantageous (Sweller, 2005b, p. 166). However, "such an assumption ignores what we now know of human cognitive architecture. Information must be processed by working memory and when dealing with novel information, working memory is extremely limited" (Sweller, 2005b, p. 166). As explained by Mayer (2001), the theoretical rationale underlying the redundancy principle is that "when pictures and words are both presented visually (i.e., as animation and text), the visual channel can become overloaded" (p. 147). Thus, requiring learners to unnecessarily coordinate and relate multiple forms of the same information or process unnecessary explanatory information imposes an extraneous cognitive load that interferes with learning" (Sweller, 2005b, p. 166).

Empirical Basis. Sweller (2005b) explains that "experimental evidence for the redundancy effect is obtained when the elimination of information from instructional material results in improved learning" (161). The effect was first demonstrated in an experimental design by Miller (1937), who used flash cards with young children – as is commonly done today – with pictorial representations of a cow alongside the word "cow." The word "cow" was also spoken. In the reduced (non-redundant) condition, the spoken word and printed word remained but the picture of the cow was removed; those learners performed better on subsequent reading tests (Sweller, 2005b, p. 161). Researchers (Chandler & Sweller, 1991) replicated the effect, named it, and concluded that processing the picture requires cognitive resources that could be devoted to learning to read the word if not dedicated to interpreting the visual stimuli as well (as cited in Mayer, 2005). In this case, the picture is redundant and interferes with what needs to be learned (Sweller, 2005b). Since Miller's (1937) demonstration, the effect has been replicated frequently (Reder & Anderson, 1980, Reder & Anderson, 1982, and Mayer, Bove, Bryman, Mars, & Tapangco, 1996, in demonstrations of summary vs. full-text redundancy; Carroll, Smith-Kerker, Ford, & Mazur-Rimetz, 1987 and Carroll, 1990, in research regarding the construction of manuals for computer applications; Chandler & Sweller, 1991, in research regarding the split-attention effect; Bobis, Sweller, & Cooper, 1993, in studies regarding text added to geometry exercise; and in follow-up studies by Chandler & Sweller, 1994 and 1996; as cited in Mayer, 2005, pp. 161-165).

In later research conducted by Richard Mayer and his colleagues on this effect (Kalyuga, Chandler, & Sweller, 1999; Mayer, Heiser, & Lonn, 2001), learners who heard narration along with animation performed better in both tests conducted for retention than did learners who heard narration along with both animation and text. For transfer of learning, those who heard narration along with animation also outperformed those learners who heard narration along with both animation and text (Mayer, 2001, p. 147).

Classroom Ramifications. Eliminating redundant information eliminates the requirement to coordinate multiple sources of information. When determining whether to add text to a diagram, designers and instructors need to consider whether the diagram by itself is self-explanatory; if it is, then leave out the text, as it would be redundant (Sweller, 2005b, p. 166). If the text adds essential information which is not in the diagram, then it should be retained (Sweller, 2005b, p. 166). Clark & Mayer (2003) add several further cautions: “Avoid narrating onscreen text when words and pictures are presented simultaneously at a fast pace” (105), however, one should consider narrating on-screen text when (a) there are no pictures, (b) the learner has ample time to process the picture and words, and (c) the learner is likely to have difficulty processing spoken words” (105).

The Coherence Principle

The coherence principle of multimedia learning stipulates that "students learn better when extraneous material is excluded rather than included" (Mayer, 2001, p. 113). The coherence principle involves irrelevant words and pictures, interesting but irrelevant sounds, and unnecessary words. According to Mayer (2001), "Student learning is hurt when interesting but irrelevant words and pictures are added to a multimedia presentation," as well as when interesting but irrelevant sounds are added (113). Student learning improves when unnecessary words are eliminated from a multimedia presentation (Mayer, 2001, p. 113). This is because "learners are actively trying to make sense of the presented material by building a coherent mental representation, so adding extraneous information gets in the way of this structure-building process" (132). Interesting but unnecessary information hinders the learning process by: (a) *distraction* – taking the learner's attention away from the relevant material, (b) *disruption* – preventing the learner from building meaningful and relevant connections, and (c) *seduction* – priming incorrect or inappropriately applied existing knowledge in an effort to organize the new information (Clark & Mayer, 2003, pp. 111-112).

Example. The temptation to spice up a presentation with entertaining or motivational elements such as dramatic stories, cutesy clip art, or background music is strong. Examples of such material to exclude would be: (a) entertaining stories, graphics, and video clips which are not essential to the instructional objective; (b) background music, sound clips, and unrelated environmental sounds – mood music; and (c) detailed textual descriptions, lessons that present content in lean text, and narration that presents the main points (Clark & Mayer, 2003, pp. 111 & 128).

Theoretical Rationale. The theoretical rationale behind the coherence principle is that interesting but unnecessary material consumes cognitive resources and diverts focus from the important material. It can also disrupt the process of organizing the material and can even prime the learner to organize the material inappropriately.

Empirical Basis. In research conducted by Richard Mayer and his colleagues on the coherence principle (Harp & Mayer, 1997; Harp & Mayer, 1998; Mayer, Heiser, & Lonn, in press; Moreno & Mayer, 2000; Mayer, Bove, Bryman, Mars, & Tapangco, 1996), learners who received concise multimedia presentations performed better on eleven out of eleven experiments than did those who received multimedia messages with extraneous material. For transfer of learning, learners who received the concise multimedia messages outperformed the learners who received multimedia messages containing extraneous material (Mayer, 2001).

Classroom Ramifications. In short, less is more. Instructors should eliminate extraneous words and pictures to a multimedia presentation, unnecessary and unrelated sounds, and keep the presentation brief and concise. As tempting as it may be to spice up a presentation with sound effects and clip art, unless these devices serve to help build mental representations and help the learner organize the material – which would be atypical – they should be avoided because their use has consistently demonstrated a hindrance to learning. As Mayer (2001) explains, "A concise presentation allows the learner to build a coherent mental representation – that is, to focus on the key elements and mentally organize them in a way that makes sense… Needed elaboration should be presented after the lesson has constructed a coherent mental representation" (133).

CONCLUSION

Contrary to expectations, the evidence has shown that over the last several decades, educational psychology has grappled with the issue of student learning through multimedia and that the research consistently fails to support the commonly-held assumption that multimedia use by itself enhances learning. In essence, as concluded by one recent research article, it is clear that ***how*** video is used is more important than ***whether*** video is used.

Early psychological studies regarding media effectiveness, which explored the persuasive use of video and the complexity of attitude change, were inconclusive. Those studies gave rise to media comparison studies, in which the effectiveness of communication or instruction from one form of media was compared to that of another form. Although hundreds of media comparison studies have been conducted, "with rare exception they have observed the same thing: *no differences in learning*" (Mayer, 2005). Consequently, media comparison studies have largely been disbanded in favor of cognitive approaches offering more empirical merit.

With that in mind, this paper explored the concept of cognitive load and introduced A. Paivio's dual coding theory as theoretical foundations to multimedia effectiveness research. Cognitive load theory, which is one of several premises undergirding Mayer's (2005) Cognitive Theory of Multimedia Learning, is based on the assumption that people have a limited capacity for working memory and an enormous long-term memory (Koroghlanian & Klein, 2004). Thus, "cognitive load theorists seek techniques to increase working memory by reducing cognitive load, which in turn should result in improved instructional design, learning efficiency, and effectiveness" (25-26). Along very similar lines is A. Paivio's dual coding theory, which claims that human cognition utilizes two distinct channels or systems for mentally assimilating new information: one which specializes in verbal information and the other which specializes in nonverbal information. Paivio's theory of memory and cognition, proposed in 1986 in his book *Mental Representations*, remains the most widely-accepted theory in cognitive psychology and has been consistently affirmed but never disproven in empirical research. In conjunction with cognitive load theory, dual coding theory forms a substantial basis for Mayer's Cognitive Theory of Multimedia Learning.

Finally, we introduced Richard E. Mayer and his Cognitive Theory of Multimedia Learning, derived from over one hundred experiments analyzing the effectiveness of various uses of multimedia. Highlighted were six well-established principles of multimedia learning which the research continues to support, including (a) the multimedia principle, (b) the split-attention principle, (c) the temporal contiguity principle, (d) the modality principle, (e) the redundancy principle, and (f) the coherence principle. In the **multimedia** principle, we affirmed that multimedia does have a place because "students learn better from words and pictures than from words alone" (Mayer, 2001, p. 63). Therefore, in preparing classroom visuals and multimedia, instructors should actively seek graphics which convey meaning and illustrate effectively whenever possible, but avoid illustrations which are merely decorative, cute, or humorous.

However, through the **split attention** principle, we learned that overall learning is negatively impacted when several sources of information which need to be mentally integrated are separated from each other, and discover that when preparing classroom visuals and multimedia, visual integration of essential information assists mental integration. Likewise, through the **temporal contiguity** principle, we learned as Mayer (2001) explained, that "students learn better when corresponding words and pictures are presented simultaneously rather than successively" (p. 96). And through the **modality** principle, we learned that presenting some information in visual mode and other information in auditory mode can expand working memory capacity and so reduce the effects of excessive cognitive load.

With the **redundancy** principle, we learned that duplicating information which isn't vital for grasping the concepts to be learned can unintentionally add to cognitive load and effectively hinder learning. Although counterintuitive, the research suggests that eliminating redundant information (particularly on-screen text when used in addition to narration) can improve learning. And from the **coherence** principle, we learned that extraneous words and pictures and unnecessary and unrelated sounds in a multimedia presentation – due to their representational potential – tend to hinder rather than enhance learning, and should be avoided. Each of these principles has solid theoretical foundations and consistent empirical support, and together they comprise a wealth of background for instructors preparing lessons which utilize multimedia for effective learning.

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