Multimedia: Designing for the Individual Learner

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Abstract

Educational psychologists have shown that learning can be more effectively facilitated when material is presented in words and pictures, rather than being presented with just words alone. Based on empirical findings, instructional strategies have been developed which utilize multimedia. The term multimedia refers to the presentation of material using both words and pictures. Schemas have also been developed to aid in the stylistic design of effective multimedia, which incorporate principles of figure/ground, hierarchy, and gestalt. In addition, six general principles of multimedia design are discussed: multimedia, spatial/temporal contiguity, coherence, modality, redundancy, and individual differences. Finally, the design of multimedia for individual differences in cognition is discussed.

Multimedia: Designing for the Individual Learner

For over a century, psychologists and educators have recognized the potential of an alliance between their specialties. A partnership that could bring into fruition a new discipline that embodies the science of psychology and the practice of pedagogy. In many ways, these fields have evolved from the changing views of learning and instruction which have directly affected research and educational practice. One of the major paradigm shifts from behaviorism to cognitive theory, which has come to dominate psychology, is now rapidly changing current educational methodology (Mayer, 1992).

In the classic behaviorist view, the learner was a passive recipient whose knowledge was shaped and reinforced by practice. Cognitive theorists, on the other hand, view learners as active participants in their construction of knowledge. Not surprising, as more psychologists became interested in researching cognitive processes, exciting and innovative approaches to instruction began to emerge.

Multimedia and Learning

One approach, which focuses on the utility of multimedia, has begun to revolutionize educational practices all around the world. The term multimedia refers to the presentation of material using both words (printed or spoken) and pictures (photos, illustrations, static or dynamic graphics). Likewise, multimedia instruction incorporates words and pictures, but with the intent of fostering learning. The case for multimedia rests on the hypothesis that learners can better understand an explanation when it is presented in words and pictures rather than just the words alone (Mayer, 2001).

Theoretical Foundations of Multimedia Learning

The rationale for using multimedia in instruction follows several assumptions concerning cognitive processes, based on a number of well-researched theories: information processing theory, dual-coding theory, cognitive load theory, and a cognitive theory of learning.

Information Processing Theory

Atkinson and Shiffrin (1968) propose a model of memory based on two types of memory, short-term memory (including sensory and working memory), and long-term memory. This theory attributes learning to the successful transfer of important information from one type of memory to the next. Short-term memory is only capable of holding small quantities of information for a limited amount of time. While long-term memory is capable of storing an infinite amount of data for an indefinite amount of time.

One of the components of short-term memory, sensory memory, can hold an unlimited amount of information for a short period of time (usually seconds), and acts as a filter by selecting specific information and ignoring other information. It directs the individual's attention to the important things, and then transfers some of that data to working memory.

Once information has made it to working memory, the key to learning is moving it to long-term memory. The problem is that this component of short-term memory is a limited system which can only hold 5 to 9 units of information at a time (Miller's study as cited in Lohr, 2003). One strategy to facilitate the transition to long-term memory is to

make the information meaningful to the learner by comparing it to something they already know.

Dual-Coding Theory

Paivio's (1990) dual-coding (or dual-channel) theory, which is related to the information processing theory, proposes that humans have two separate memory systems for processing information: verbal and imaginal, and that these systems can activate each other. For example, concrete words (words that are easily visualized like a person, place or thing) have the ability to stimulate nonverbal or imaginal memory. Abstract words (ideas or emotions), on the other hand, are less likely to stimulate nonverbal memory and are less likely to be remembered. Thus, when both systems are being activated, the potential to learn is much greater.

Cognitive Load Theory

The theory of cognitive load is in some ways an extension of the dual-coding theory. It is based upon the idea that humans are limited in the amount of information that can be processed in each channel (verbal or imaginal) at any one time. The theory suggests that effective instructional materials facilitate learning by directing cognitive resources toward activities that are more relevant to learning rather than extraneous information.

Chandler and Sweller (1991), and Sweller and Chandler (1994), have determined two major sources of intrinsic and extraneous cognitive load. *Intrinsic cognitive load* depends on the number of elements in the material and how they interact, which is a

determinant of how intrinsically difficult it is to process. *Extraneous cognitive load* depends on how the material is organized and presented (i.e. its design characteristics). When information is presented poorly or contains nonessential explanatory material, learners must engage in irrelevant or inefficient cognitive processing, which can have deleterious effects (Tardieu and Gyselinck, 2003).

Cognitive Theory of Multimedia Learning

Mayer (1997, 2001) has incorporated aspects of all three previously mentioned theories to formulate a cognitive theory of multimedia learning. This theory suggests that learning is facilitated most effectively when words and visuals are designed to help individuals select, organize, and integrate information in ways that are meaningful to them (see Figure 1). Implications and techniques for the design of instruction, based upon this theory, are described succinctly for constructivist learning in Mayer (1999).

Lohr (2003), in an effort to delineate a more stylistic methodology based on Mayer's theory, describes principles of figure/ground, hierarchy, and gestalt, which were derived from research conducted on artificial intelligence and memory. The basic premise of these findings is that a certain degree of human perception is predetermined–-the unconscious mind detects the boundaries and features of an image first and then our conscious mind fills in the rest (Marr's study, as cited in Lohr, 2003).

Selection.

This process of "filling in" is the basis for the figure/ground principle, which states that "during perception the mind seeks to identify and separate figure and ground

elements in an image" (Lohr, 2003, p.39). This mental process is important when it comes to using art in multimedia, because in order to help the individual select what they need to learn, the information should be presented in a way that the mind is predisposed to grasp.

Organization.

Lohr's (2003) hierarchy principle is derived from research showing that working memory stores information in chunks. The mind has a tendency to group information and organize it in a hierarchical fashion. In terms of presenting information using visuals, it is a good idea to incorporate items like arrows, lists and outlines as a way to establish a hierarchy.

Integration.

The last principle, gestalt, encompasses both figure/ground and hierarchy, and is based on the belief that the whole is greater than the sum of its parts. For the learner, this means being able to integrate the information which is presented in a way that is meaningful to them. This principle supports the idea that combining text and visuals will facilitate more effective learning than either being presented independently (Lohr, 2003; Schnotz, 2002).

Six Principles of Multimedia Design

According to Mayer (2001), there are two ways in which an educator can approach multimedia learning: 1) as information acquisition, or 2) knowledge

construction. Information acquisition is the process by which information is added to the memory of a passive learner. In this approach, the educator is merely the information provider and the multimedia is a delivery vehicle. On the other end of the spectrum, knowledge construction is the process of building a coherent mental representation. In this approach, the learner takes an active role in making sense of the information and the educator serves as a cognitive guide.

Multimedia Principle

The goals of multimedia presentation, based on these approaches, are obviously very different. The goal of the knowledge acquisition view of instruction is to present learners with vast quantities of information in the most efficient way possible. This type of learning is usually assessed by retention tests in which the learner is expected to remember what was presented, and then recognize or reproduce the material on the test.

The second goal, which is consistent with the knowledge construction view, is to help learners understand the material and then be able to use what they learned in novel situations. This type of learning is assessed by transfer tests in which the learner must solve problems that were not explicitly stated in the instructional materials, and their performance demonstrates how well they can use what they learned.

In Mayer and Gallini (1990), several experiments were conducted to compare the retention and transfer performance of students who received text with dynamic illustrations of how scientific devices work to those who received the same expository passages without the illustrations. Their results indicated that the illustrations

consistently improved performance on recall of conceptual information and creative problem solving. Mayer and Anderson (1992) conducted a similar study using animations and narration. Their results indicated that retention and problem solving requires the construction of representational and referential connections, which is consistent with the dual-coding model.

Mayer (2001) labels this pattern of results the *multimedia effect for retention and transfer*. In terms of retention, the multimedia effect is that learners perform better on verbal retention when presented with text and illustrations or narration and animation. In terms of transfer, the effect is that students perform better on problem-solving transfer when they learn from text and graphics rather than text alone.

Spatial and Temporal Contiguity

This principle, which is also consistent with the dual-coding model, assumes that students learn better when corresponding words and pictures are presented near rather than far from each other in space and time (Mayer, 2001). To provide empirical rationale for this claim, a study was conducted by Mayer and Sims (1994), in which students were classified as having high or low spatial ability, and then asked to view a computer-generated animation with narration that was either presented concurrently or successively.

Their results, in support of the importance of temporal contiguity, showed that the concurrent group “generated more creative solutions to subsequent transfer problems than did the successive group.” In support of the importance of spatial contiguity, individual’s with high spatial ability are able to “devote more cognitive resources to

building referential connections between visual and verbal representations of the presented material," whereas those with low spatial ability "must devote more cognitive resources to building representational connections between visually presented material and its visual representation" (p.389).

Coherence

Derived from the cognitive load theory, the coherence principle states that students learn better when material is presented without extraneous information. Including non-essential material forces the learner's cognitive processes to compete for resources in the working memory. This can cause the learner's attention to be diverted from what is important, in addition to disrupting their cognitive organization of the material. As a result, the learner may begin to organize the information in a way that is inefficient or inappropriate (Mayer, 2000; 2001).

Modality

The principle of modality was derived from both cognitive load and the dual-coding theory. It states that individuals learn better when verbal information is presented in spoken word (auditory) rather than as printed text (visually). The theoretical rationale behind this principle is that when both kinds of information (pictures and words) are presented visually, the visual channel becomes overloaded. If the information is presented using both pictures and spoken words, the load is distributed and both channels are used (Mayer, 2000; 2001).

Redundancy

Directly related to the modality principle, the redundancy principle states that individuals are able to learn better when animation and narration are presented, rather than animation, narration, and text, when in both cases the information is presented simultaneously. The theoretical rationale for this is the same as the modality principle--when both kinds of information (pictures and words) are presented visually, the visual channel becomes overloaded (Mayer, 2000; 2001).

Individual Differences

One of the challenges of designing instructional materials, which are effective for a variety of learners, is accounting for their individual differences in terms of prior knowledge and spatial ability. Mayer's (2001) individual differences principle is based upon evidence that low-knowledge and high-spatial learners benefit more from design effects than high-knowledge or low-spatial learners.

The theoretical rationale that Mayer provides for this principle is that low-knowledge learners spend more time trying to integrate the presented information when it lacks guidance because they do not have the prior knowledge, unlike high-knowledge learners. If the presentation incorporates design principles, then they have more cognitive resources to process and integrate the material. Similarly, low-spatial learners must devote more cognitive energy when trying to integrate visual and verbal representations than learners who have high-spatial abilities.

Designing Multimedia for the Individual Learner

Effectively facilitating learning in ways that capitalize on the individual differences in learner's abilities and preferences is an important aspect of multimedia design. In Gardner's (1999) theory of multiple intelligences, he discusses a variety of methods that can be integrated into the instructional material to help foster an individual's understanding. The primary methods that are discussed include selecting fewer topics, which can be easily connected to larger themes, but are focused on in greater depth; using "entry points" which engage the learner in the topic; using analogies, metaphors and examples; and "approaching the core" by using multiple representations to convey the overall meaning of the topic. In terms of engaging the learner in the topic being taught, Gardner suggests using the following general strategies or entry points, which are specific to the type of intelligence (narrational, quantitative/numerical, foundational/existential, aesthetic, hand-on, and social).

For the individual with a narrational intelligence or strength, incorporating stories into the instructional material may provide better facilitation of understanding. When someone is interested in numbers and data, they may benefit from the use of statistics and quantitative patterns presented within the material. Placing the topic in the framework of broad philosophical issues may help individuals who think about things from an existential perspective or intelligence. One whose strength lies in the realm of aesthetics would benefit from instruction which incorporates the use of art and artistic perspectives. Someone who excels at doing things with there hands would most certainly benefit from activities that get the student actively involved. Lastly, for those

who are socially intelligent, the use of groups and collaborative assignments are most effective for facilitating their understanding of the material (Gardner, 1999).

On a more general scale of intelligences, Mayer and Massa (2003) conducted a study assessing individuals in terms of verbal and visual processing ability. They utilized 14 cognitive measures related to verbal and visual differences in individual learning styles. According to the results of their analysis, there are four main factors that influence how well a person is able to learn: cognitive style, learning preference, spatial ability, and general achievement.

The implications of their results confirm the importance of assessing individual learners in order to tailor instruction to their particular needs. In terms of cognition, they found that the use of questionnaires is effective for assessing visual-verbal cognitive processing styles. To assess learning preferences, utilizing behavioral and rating instruments involving multimedia learning scenarios is effective. Incorporating the use of visualization and spatial relations tests and self-ratings of verbal-spatial ability are most effective for assessing spatial ability, and tests of verbal and mathematical achievement are best for gaining a sense of the general achievement abilities of the learner.

Conclusion

In conclusion, designing multimedia using these principles has been proven to effectively facilitate learning, especially when the individual differences of the learners are taken into consideration. Instructional design has made an important progression toward a more learner-centered educational approach by focusing on the cognitive

processes of the learner through empirical research. In order for individuals to have equal access to real-world opportunities, it is crucial that education as a whole evolve from the more behaviorist principles of information acquisition and retention, which are still used today, to more cognitive-based principles of knowledge construction and transfer. Everyone has the right to the best education available, which will afford them the most opportunities in life, and to do that the most effective and empirically valid instructional strategies should be utilized including multimedia.

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Figure Captions

Figure 1. Dual-coding channels (verbal-top row; pictorial-bottom row) in a cognitive theory of multimedia learning.

Appendix

Tables and Figures

Figure 1.