Learner-Centered Principles for Multimedia Lesson Design

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Abstract

This paper explores research on how to increase meaningful learning from multimedia lessons by building these lessons based on principles that reflect the way people learn. This learner-centered approach references the cognitive theory of multimedia learning which makes the assumptions that the human mind is a dual-channel, limited-capacity, active-processing system. There are three types of associated human learning processing that multimedia lesson designers should consider by following certain principles for design. The first type is extraneous processing, which inhibits meaningful learning and should therefore be reduced. Research has demonstrated that this can be achieved by following the coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principles (Johnson & Mayer, 2012; Mayer, 2009). The second type is essential processing, which can be managed by adhering to the segmenting, pre-training, and modality principles (Mayer, 2009; Rummer, Schweppe, Fürstenberg, Scheiter, & Zindler, 2011; Wiebe & Annetta, 2008). When extraneous processing is reduced and essential processing managed, designers should foster generative processing by using the multimedia and personalization principles (Kartal, 2010; Kulasekara, Jayatilleke, & Coomaraswamy, 2011; Mayer, 2009). Based on supporting research, there is enough information to show that following these learner-centered principles in multimedia lesson design, while considering found boundary conditions, will foster meaningful learning.

Learner-Centered Principles for Multimedia Lesson Design

Studies have been conducted on how to increase meaningful learning from multimedia lessons by building these lessons based on principles that reflect the way people learn. This learner-centered approach references the human learning processes that are central to the cognitive theory of multimedia learning, from which the principles are derived. Mayer (2009) proposes these principles for designers to refer to when building effective multimedia lessons: coherence, signaling, redundancy, contiguity (spatial and temporal), segmenting, pre-training, modality, multimedia, and personalization. Various research has found support for each of these ten principles, as well as certain boundary conditions (Johnson & Mayer, 2012; Kartal, 2010; Kulasekara, Jayatilleke, & Coomaraswamy, 2011; Mayer, 2009; Rummer, Schweppe, Fürstenberg, Scheiter, & Zindler, 2011; Wiebe & Annetta, 2008). Based on this research, there is enough information to show that following the learner-centered principles and boundary conditions in multimedia lesson design will foster meaningful learning.

Cognitive Theory of Multimedia Learning

Human learning processes are central to the cognitive theory of multimedia learning, which Mayer (2009) explains is based on the following assumptions: “the human information processing system includes dual channels for visual/pictorial and auditory/verbal processing, each channel has limited capacity for processing, and active learning entails carrying out appropriate cognitive processing during learning” (p.57). Active learning does not refer to behavioral activity, but to cognitive sense-making which includes selecting relevant words and images, organizing them into coherent verbal and visual representations, and integrating these representations with prior knowledge (Mayer, 2009). There are three main types of cognitive processing that can occur during learning: extraneous (does not serve the instructional goal;

caused by poor design), essential (needed to represent the material in working memory; determined by the material complexity), and generative (deep cognitive processing that includes organizing and integrating the material) (Mayer, 2009). To build effective multimedia lessons, designers should practice techniques for “reducing extraneous processing, managing essential processing, and fostering generative processing” (Mayer, 2009, p. 57).

Principles for Reducing Extraneous Processing

Extraneous processing should be minimized because when extraneous material is included and/or the instructional design is confusing, learners waste valuable cognitive capacity when actively trying to make sense of presented material. In order to avoid overload of learners’ processing channels, Mayer (2009) advises that it is important to design a lesson concisely and according to the instructional goal, and proposes five principles for multimedia lesson designers to follow: coherence, signaling, redundancy, and spatial and temporal contiguity.

Coherence

The coherence principle states that learning is improved when interesting but irrelevant words/pictures, sounds/music, and words/symbols are excluded from a multimedia presentation, and is based on the theory that “extraneous material competes for cognitive resources in working memory and can divert attention from the important material, disrupt the process of organizing the material, and prime the learner to integrate the material with an inappropriate theme” (Mayer, 2009, p. 89). To verify this principle and its impact on meaningful learning, Mayer (2009) and colleagues performed fourteen tests that compared transfer test results between learners who received concise multimedia presentations versus those that received presentations with extraneous material. Presentation content covered lightning, brakes, and ocean waves. In thirteen out of fourteen tests, transfer performance was better in the concise groups, indicating that meaningful learning was fostered, and supporting the coherence principle (Mayer, 2009). As Mayer notes in the boundary conditions, meaningful learning may particularly be fostered by this principle for learners with low domain knowledge or working memory capacity.

Signaling

Like the coherence principle, the signaling principle is aimed at reducing extraneous processing. It states that “people learn better when cues that highlight the organization of the essential material are added” (Mayer, 2009, p. 108). Mayer (2009) lists cues that are verbal (outline sentences, headings, vocal emphasis, pointer words) and visual (arrows, distinctive colors, flashing, pointing gestures, graying out). Adding cues like these will help minimize extraneous processing by guiding both the learners’ attention to the main points in the lesson and their organization of that essential material into a logical structure. Mayer and colleagues assessed this principle with six tests that compared the transfer performance between signaled and nonsignaled groups after viewing multimedia presentations on lightning, airplanes, and biology. While the signaled groups outperformed the nonsignaled groups in five of the six tests, Mayer (2009) states that the overall results indicate “promising but preliminary” (p. 114) support for the signaling principle, and favor the benefits of verbal more so than visual signaling. Boundary conditions suggest that signaling may be especially helpful when used sparingly, with low-level readers, and when the lesson is disorganized or contains extraneous material (Mayer, 2009).

Redundancy

The redundancy principle is also meant to help people learn by keeping human learning processes in mind, and proposes that learning is enhanced when just graphics and narration are presented, rather than graphics, narration, and printed text (Mayer, 2009). Mayer (2009) proposes this principle because, when redundant text is presented, extraneous processing occurs as the learners must scan between the graphics and text, as well as mentally compare the text with the narration. Mayer and colleagues found consistent evidence for the redundancy principle in each of the five tests they performed, comparing transfer test results between nonredundant and redundant groups based on multimedia presentations about lighting and an environmental science game. In other multimedia learning research, Wiebe and Annetta (2008) found that certain eye tracking data “seems to support [the redundancy effect], in that [on the] slides with static graphics, the low density printed text is ‘sticky,’ holding the visual attention of the student even when narration is added” (p. 272). Found boundary conditions reduce the applicability of the redundancy principle for situations in which extraneous processing is already diminished when “captions are shortened to a few words and placed next to the part of the graphic they describe,…spoken text is presented before the printed text rather than concurrently,… and there are no graphics and the verbal segments are short” (Mayer, 2009, p. 118).

Contiguity

The last two principles that Mayer advises multimedia designers to consider, when building lessons with the intent to reduce learners’ extraneous processing, are the spatial and temporal contiguity principles. These principles propose that people learn better when corresponding words and pictures are presented next to each other on the page or screen (spatial contiguity), or at the same time (temporal contiguity), as opposed to being presented in a separated or successive manner (Mayer, 2009). The reasoning behind these principles is that when words and pictures are presented contiguously in time or space, they can be more easily held in working memory at the same time, encouraging meaningful learning through the building of connections.

Spatial. The spatial contiguity principle was confirmed by five out of five tests conducted by Mayer (2009) and colleagues in which groups that viewed integrated presentations on lighting and brakes performed better on transfer tests than did the separated presentation groups. Later research by Johnson and Mayer (2012) further confirmed this principle through tracking eye movements of learners viewing integrated and separated presentations on car brakes: “The results of the eye movement analyses help to clarify changes in cognitive processing during learning caused by spatial contiguity. In an integrated presentation, the words and pictures are presented in such a way to foster more meaningful learning” (p. 189). Boundary conditions for the spatial contiguity principle imply that it is more effective when learners are unfamiliar with the material and/or it is complex, and when the picture is not entirely understandable without words (Mayer, 2009).

Temporal. The temporal contiguity principle was also confirmed by Mayer (2009) and colleagues. In all eight tests over presentations on tire pumps, brakes, lungs, and lightning, the simultaneous presentation groups outperformed the successive groups on transfer tests. Boundary conditions state that the temporal contiguity principle may be less applicable when a successive lesson involves alternations between small segments as opposed to a long continuous presentation, or is under learner instead of system control (Mayer, 2009).

Principles for Managing Essential Processing

Reducing extraneous processing by following principles such as temporal and spatial contiguity will help make room, cognitively-speaking, for learners to process essential material, which is “the core information from the lesson that is needed to achieve the instructional goal” (Mayer, 2009, p. 171). In situations when the learner is inexperienced, the material is complex, and/or the lesson is fast-paced, essential processing overload may occur, in which not enough cognitive capacity is left to allow deeper processing. Therefore, multimedia designers should build lessons that are compatible with how people learn, by managing essential processing through the use of the principles of segmenting, pre-training, and modality (Mayer, 2009).

Segmenting

The segmenting principle helps manage learners' essential processing, and consequently fosters meaningful learning, by presenting multimedia messages in user-paced segments rather than as a continuous presentation (Mayer, 2009). Mayer (2009) explains that this creates "more manageable parts that can be processed sequentially rather than all at once" (p. 186). Studies conducted by Mayer and colleagues tested this principle with animated presentations that covered lightning and electric motors. In three out of three tests, the segmented groups outperformed the continuous groups on transfer tests. Mayer refers to research that also confirms this principle in the context of worked-out examples and complex graphs. Boundary conditions indicate that the segmenting principle is most relevant when the presentation is fast-paced and/or has complex material, and when the learner is unfamiliar with the material (Mayer, 2009).

Pre-training

Another principle that is especially helpful when the learner is unfamiliar with the material is the pre-training principle, which states that more meaningful learning takes place from a multimedia presentation when learners already know the names and characteristics of the key concepts (Mayer, 2009). Inserting a pre-training episode to teach learners these names and characteristics will help avoid essential processing overload by distributing some of the essential processing to before the main lesson. Mayer (2009) and colleagues found consistent support for this principle in each of the five tests they performed, comparing transfer test results between pre-training and no pre-training groups over multimedia lessons on brakes, tire pumps, and a geology game. In addition to being effective when learners are unfamiliar with the material, the pre-training principle boundary conditions also include effectiveness when the lesson is fast-paced and the material is complex (Mayer, 2009).

Modality

Like the pre-training principle, the modality principle can be used by multimedia designers to help manage learners' essential processing in order to avoid overload. This principle states that "[p]eople learn more deeply from pictures and spoken words than from pictures and printed words" (Mayer, 2009, p. 200). When learners must process pictures and printed words at the same time, the visual channel can easily become overloaded. However, when designers follow the modality principle by choosing narration instead of printed text to accompany pictures, some processing is shifted to the verbal channel. Mayer and colleagues found strong support for this principle through studies using presentations on lightning, brakes, aircraft simulation, biology, and an environmental science game. In all seventeen tests, "people learned better on transfer tests after learning with graphics and narration rather than graphics and printed text" (Mayer, 2009, p. 211). In other research using eye-tracking methods and multimedia lessons on scientific phenomena, Wiebe and Annetta (2008) state that "the predictions of the effect of media manipulations made by cognitive load and multimedia learning theory… are supported by these findings that narration can have a significant impact on how attentional resources are divided between the text and graphics" (p. 271). Rummer et al. (2011) also found support for the modality principle in research using multimedia lessons on fictitious stellar constellations. Their findings showed that "learners' picture recognition performance decreased when processing text in written rather than spoken form" (p. 172). Rummer et al. (2011) go on to state that "this effect is likely to occur especially under conditions in which learners have to allocate their limited time resources to either reading or viewing the picture (i.e., under system control)" (p. 172). Other boundary conditions suggest that the modality principle is primarily relevant for complex material and for learners familiar with the words, but less so for hearing-impaired learners or non-native speakers, or when the lesson includes technical words/symbols (Mayer, 2009).

Principles for Fostering Generative Processing

When multimedia lesson design helps manage learners' essential processing and reduce extraneous processing, learners' should have ample remaining cognitive capacity to participate in generative processing, which is "aimed at making sense of the material and includes organizing the incoming material into coherent structures and integrating these structures with each other and with prior knowledge" (Mayer, 2009, p. 221). Even if designers successfully follow principles to help learners free up cognitive capacity for deeper processing, they must also design in a way that makes sure learners are motivated to use that capacity for generative processing. Two principles that Mayer (2009) proposes to assist in this are multimedia and personalization.

Multimedia

The multimedia principle suggests that people learn better from lessons with words and pictures, rather than just words. Mayer (2009) explains that this principle is derived from the rationale that including pictures along with words will cause learners to be more motivated to "construct verbal and visual mental models and to build connections between them" (p. 223). This rationale refers to the dual-channel assumption of the cognitive theory of multimedia learning; and this learning theory is supported by the research of Mayer and colleagues that showed representing material by both words and pictures increased transfer test performance. In eleven out of eleven studies covering the topics of brakes, pumps, generators, lightning, and arithmetic, the multiple-representation groups outperformed the single-representation groups, demonstrating enhanced understanding of the material. Kulasekara et al. (2011) also found benefits for including pictures, especially animations, when teaching complex scientific material: “This study brought to light how easy it was for the learners to comprehend complex dynamic bacterial genetic processes using well-designed [interactive multimedia] compared with lengthy explanations in print course material” (p. 122). This research also throws light on “designing effective learner-centred multimedia learning material” (Kulasekara et al., 2011, p. 125). Like other principles, the multimedia principle is effective because it is based on how people learn. This is seen in its boundary condition which suggests that since learners’ understanding is in direct relation to their ability to cognitively organize and integrate material, low-knowledge learners are most likely to benefit from the multimedia principle as they need more guidance in building verbal/pictorial connections (Mayer, 2009).

Personalization

In addition to using effective pictures with words, designers can observe the personalization principle to increase learner motivation, which will help deepen learning by fostering generative processing. This principle proposes that learning is enhanced when multimedia presentations contain words that are less formal and more conversational in style, because “[w]hen learners feel that the author is talking to them, they are more likely to see the author as a conversational partner and therefore will try harder to make sense of what the author is saying” (Mayer, 2009, p. 242). Mayer (2009) found strong support for the personalization principle throughout eleven studies using both narration and text in lessons on lightning, botany, lungs, and engineering. In these studies, the personalized groups consistently outdid the nonpersonalized groups on transfer tests. Similarly, Kartal (2010) found comparable results using a lesson on stellar evolution and death presented to three groups with varying levels of personalization. The personalized informal group, in which the style was “conversational, with direct comments to the user” (Kartal, 2010,

p. 617), showed better learning gains on transfer tests, and additionally, seemed to increase learner interest. These findings indicate deeper learning occurred (as seen in generative processing) due to the use of a more conversational style. Mayer warns that designers should not overdo personalization, however, or the principle will become ineffective. Another boundary condition suggests that this principle is more helpful to learners who are beginners. The personalization principle is closely connected to the voice principle which suggests that people learn better when narration is personalized by being spoken in a friendly human voice rather than a machine voice (Mayer, 2009). Mayer found results consistent with this principle in three studies using lessons concerning lightning and mathematics word problems, but advises that this is only preliminary evidence in the search for ways to foster generative processing.

Conclusion

Mayer (2009) presents a "cognitive theory of multimedia learning that is based on three basic assumptions about how the human mind works—namely, that the human mind is a dual-channel, limited-capacity, active-processing system" (p. 70). Ten principles for the design of multimedia lessons have been tested and subsequently supported that take into account these basic assumptions by reducing extraneous processing (coherence, signaling, redundancy, spatial contiguity, and temporal contiguity), managing essential processing (segmenting, pre-training, and modality), and fostering generative processing (multimedia and personalization). Mayer advises that "instructional design involves not just presenting information, but also presenting it in a way that encourages learners to engage in appropriate cognitive processing" (p. 168). Since the recommended principles and corresponding boundary conditions are compatible with the human learning processes, designing multimedia lessons based on them will foster meaningful learning.

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