Understanding Multimedia Learning:

Integrating multimedia in the K-12 classroom

Multimedia offers exciting possibilities for meeting the needs of 21st century learners. The use of multimedia instruction can significantly enhance student learning if properly designed and implemented. This paper describes the way in which the brain processes multimedia information and the principles behind effective multimedia instruction.

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Overview

Multimedia offers exciting possibilities for meeting the needs of 21st century learners. Multimedia learning can be defined in a number of ways. For the purposes of this paper we define multimedia learning as the delivery of instructional content using multiple modes that include visual and auditory information and student use of this information to construct knowledge.

Today's K-12 students are very different from even their recently graduated peers. These students are **digital natives**, a term attributed to futurist Marc Prensky to distinguish between those who have grown up with technology and those who have adapted to it. They live in a world in which digital technology is part of the texture of their daily lives. They have never known a world without technology. Technology is their "native language" and they expect to use technology in school.

While some students have greater access to technology than others, computers with Internet access are now nearly universally available in American schools. Internet-enabled computers and cell phones are pervasive outside of school. Use of technology by 5-18 year olds is at its highest level and is projected to increase.

This increased reliance on technology combined with what we know about brain processing, offers enormous potential for instruction. Research has shown us that the brain processes information using two channels—visual and auditory. When information is presented using both channels, the brain can accommodate more new information. By taking advantage of this multimodal processing capability and technology-based tools, we can dramatically enhance student learning through multimedia instruction.

How the brain processes information

We are at the beginning of a revolution in neuroscience, and yet we know more about how the brain processes information than ever before. While a complete technical discussion of information processing and the brain are beyond the scope of this paper, to understand how multimedia can help students learn it is important to understand the basics of how the brain processes information.

How we process information

Our ability to process information is a multi-step process that involves the perception, attention, selection, organization and integration of information (Sweller, 2003). At the center of this process is **long term memory**. As the name implies, our long term memory stores our accumulated knowledge. Our accumulated knowledge is organized into "chunks" of information in what are known as **schema**. Schemas allow us to organize information in meaningful ways and help us integrate and organize new information (Chi, Glaser, and Rees, 1982). In short, our long term memory is where what we know is stored and where we integrate new information. If information does not find its way into long term memory, it is lost. Learning can be thought of as change in our long term memory.

The limitations of working memory

Before information can be integrated into long term memory it must be received and processed by our **working memory**. Working memory is very limited; it can only handle small amounts of information before it has to be integrated into our long term memory or lost. In his landmark article on this subject, George Miller (1956) suggested that we can only process about seven pieces of information at one time. And, we must do so quickly, as working memory can only keep information for about 20 seconds.

Multiple channels for information processing

Researchers now believe that there are multiple channels in working memory. Baddeley (1992) proposes an auditory and a visual channel. The auditory channel handles information that is heard, while the visual channel processes information that is seen. Text seems to have unique processing requirements, with words initially captured by the visual channel and then converted to sounds in the auditory channel (Mayer, 2005).

Research suggests that the visual channel handles less information than the auditory channel (Miler, 2005). However, when information is presented using both the visual and auditory channels, working memory can handle more information overall.

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Using multiple channels can increase the amount of information that the brain can process (Sweller, 2005). But, there is still the risk of cognitive overload. Too much information delivered in an ineffective manner can interfere with the brain's ability to successfully integrate information into long term memory.

Organizing information using schema

The information in working memory is integrated into long term memory using existing schema (Sweller, 2003). If there are no existing schema in which to "fit" the information, new schema need to be created and working memory may need to do some extra work to help organize the information (Baddeley 1999). If information is poorly organized, or if it is difficult to relate newly presented information to existing schema, working memory can handle even less information. This can be prevented somewhat by presenting organizing information along with the information to be learned.

Brain Processing and Multimedia Learning

So what do we know about brain processing that is relevant to multimedia learning? We know that:

1. Effective multimedia recognizes that working memory has a limited capacity to process information.

2. Effective multimedia presentations take advantage of both the auditory and visual channels in working memory to deliver content. Using multiple channels increases the overall amount of information the brain can process.

3. Effective multimedia understands that text may be particularly challenging to process, with involvement from both the visual and auditory channels required.

4. Effective multimedia presentations recognize that long-term memory organizes information into meaningful chunks called schema. Presenting information in a way that makes use of existing organizing structures (schema) or that helps students organize the information can greatly assist the learner in incorporating information into Long Term memory.

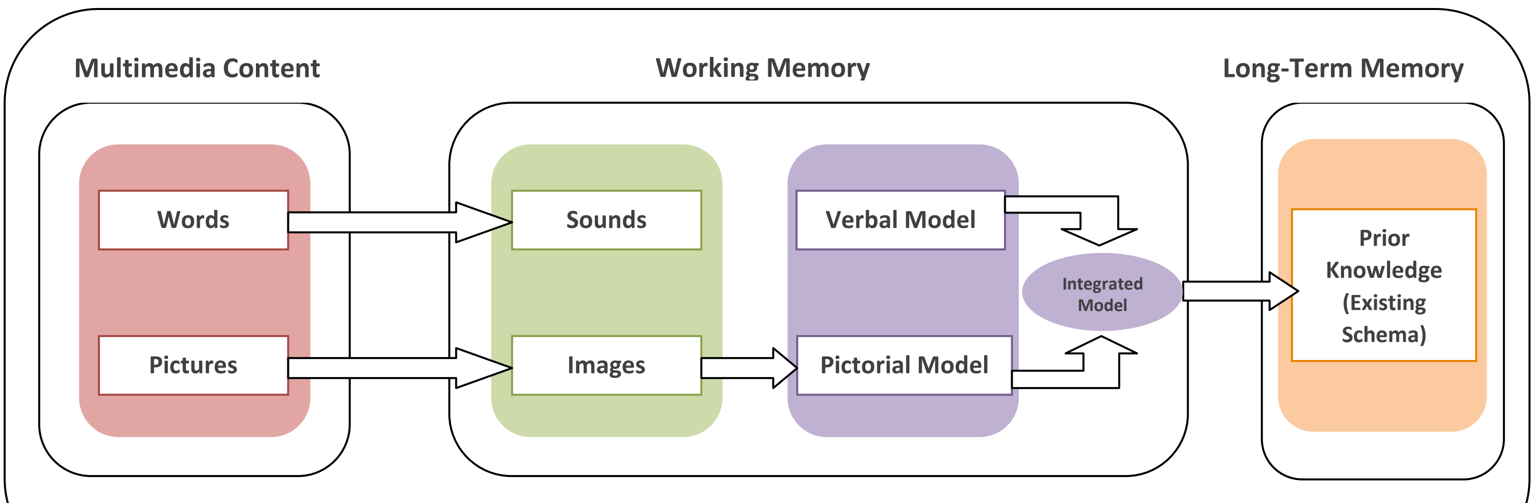

Figure 1: Information Processing Model based on Mayer (2005)

Good multimedia instruction is driven by an understanding of how the brain processes information. The most effective multimedia applications take advantage of this knowledge.

What does effective multimedia look like?

There is a growing body of research exploring what makes multimedia effective. Below, we identify some of the most important principles of multimedia learning and what the research says about how they contribute to student learning.

Words and pictures are better than words alone.

The fundamental principle behind multimedia learning is best described by Richard Mayer (2005), one of the leading researchers in this area: "People learn better from words and pictures than from words alone." In this context, words include written and spoken text, and pictures include static graphic images, animation and video. That using both words and pictures is more effective than words alone should not be surprising in light of what we know about how the brain processes information. Research tells us that the use of both words and pictures lets the brain process more information in working memory (Sweller, 2005).

Extending this basic principle, Mayer (2005) and his colleagues tell us that narration and video is much more effective than narration and text. Similarly, narration and video appear to be more effective than narration, video and text. Narration and text rely on the same channel to process information (Baddelley, 1999). It seems that text heavy multimedia presentations may be less effective than those that rely on narration.

Recall that for learning to take place, information from working memory must successfully make its way to long term memory. By using multiple channels of working memory, multimedia content can increase the likelihood that information will be effectively integrated into long term memory and not lost. For example, a narrated animation that balances the presentation of content between the animation and the narration (and keeps the amount of text to a minimum) is more likely to be effective.

Multimedia learning is more effective when learner attention is focused, not split.

Multimedia applications are more effective when learner attention is not split. Split attention occurs when the learner is forced to attend to information that is far apart, such as when content is visually far apart on the screen or if it is presented at two separate points in time. In short, when related content is presented together in time and visually, learning is more effective (Mayer, 2005). When related content is not presented together, learner attention is split and the brain has more work to do to integrate the disparate sources of information.

Words and pictures presented simultaneously are more effective than when presented sequentially (Mayer and Sims, 1994). For example, narration and animation presented together are more likely to contribute to student learning than the presentation of narration and then animation (or animation and then narration).

Multimedia applications that have text and pictures presented in close proximity (or that may overlap) are more effective than those applications that present text and pictures far apart on the screen. When text is included with video or graphic information, it should be presented in close proximity to the pictures. Learners studying integrated information outperform learners studying the same information where attention is split (Chandler and Sweller, 1991). Integrated formats (e.g., presenting information on a single screen) are preferable to separate media (e.g., presenting information on screen and on a separate sheet of paper).

The presentation of multimedia content should exclude extraneous and redundant information.

Research suggests that multimedia learning is most effective when it includes only content that is relevant and aligned to the instructional objectives (Mayer, 2003). Kalyuga, Chandler and Sweller (1999) found that students learned more when extraneous and redundant information was not included in a multimedia presentation.

Learning is most effective when interesting and irrelevant information is eliminated because of the brain's limited information processing resources.

"Wasting" the brain's limited resources on extraneous information is a detriment to learning. Precious brain resources should be focused on essential information aligned to instructional goals. Multimedia designers and users would do well to resist the temptation to present extraneous information.

It is important to distinguish between redundant information—which in this context means information presented at the same time—and instruction presented before and after exposure to multimedia content to prepare, reinforce or extend learning from the multimedia content. The activity preceding presentation of multimedia content and the activity following information are critical, as we will see when we examine other important principles of effective multimedia learning.

Multimedia learning is more effective when it is interactive and under the control of the learner.

Not all students learn at the same pace. Research tells us that when learners are able to control the pace of the presentation they learn more (Mayer, Dow, and Mayer, 2003).

Multimedia presentations are more effective when the learner has the ability to interact with the presentation, by slowing it down or by starting and stopping it. This pacing can also be achieved by breaking the presentation into segments; shorter segments that allow users to select segments at their own pace work better than longer segments that offer less control.

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Multimedia learning is more effective when learner knowledge structures are activated prior to exposure to multimedia content.

Learning from multimedia presentations is enhanced when the structures for organizing the information are activated (Pollock, Chandler, and Sweller, 2002). Helping students recall or acquire structures that will help them organize and understand the information can be accomplished in several ways. Activation can be accomplished by allowing students to preview the content though demonstrations, discussion, directed recall and written descriptions. These preview activities should be directed at activating prior knowledge (Kalyuga, 2005), signaling what is important, and showing how the content is organized. Reviewing terminology that will be encountered, presentation of graphic organizers, class discussion, and assessments can also be helpful in activating prior knowledge.

Recalling our earlier discussion about how the brain processes information, these preview activities help activate existing schema (organizing structures) and create new schema to make it easier to absorb the new information in the presentation. Activating knowledge helps provide a structure from long term memory to understand and organize the new information from working memory.

Multimedia instruction that includes animation can improve learning.

When used effectively, animated content can improve learning. Several studies have suggested that learning is enhanced in computer-based animation environments (Park, 1994; Tversky, Bauer-Morrison and Betrancourt, 2002). Animation appears to be most effective when presenting concepts or information that students may have difficulty envisioning (Betrancourt, 2005). Animation can help the student visualize a process or other dynamic phenomenon that cannot be envisioned easily. This is especially true for processes that are not inherently visual (e.g., electrical circuits, forces in physics).

Animation seems to work better with novices than experts (Mayer and Sims, 1994). Students who are less familiar with the content in question are likely to benefit more than those who have more familiarity with the content. Animation also appears to be more effective when students have the ability to start and stop the animation and view it at their own pace or are able to manipulate various facets of the animation. When provided with the ability to interact with the application in this way, students seem to both enjoy the experience more and perform better when tested on the content (Mayer and Chandler (2001).

By enabling students to visualize complex information, animation may make it easier for the learner to make sense of the information in a way that requires less processing. In addition, animation is more likely to be effective if it is accompanied by narration, which makes use of both the auditory and visual channels.

Multimedia leaning is most effective when the learner is engaged with the presentation.

Multimedia is most effective when the content and format actively engage the learner. Active engagement helps the student construct knowledge and organize information into meaningful schema (Mayer 2003). Research tells us that there are several ways in which we can make multimedia presentations more engaging.

"The use of onscreen characters can increase student engagement. This is especially true when the onscreen character appears to interact with the learner."

Multimedia that is more personalized engages learners more than multimedia that is less personalized (Mayer, 2005a). Presentations that have a more conversational tone tend to be more engaging than those that have a more formal tone. And, presentations that use the more familiar "you and I" are more engaging than those that present in the third person (Mayer, 2005a). Learners tend
to find presentations that use a familiar voice with a familiar accent more engaging than those that use a less familiar voice and accent (Mayer, Sobko and Mautone, 2003).

The use of onscreen characters can increase student engagement. This is especially true when the onscreen character appears to interact with the learner (Craig, Gholson and Driscoll, 2002). Presenting educational concepts in a "story" format can also be effective in engaging students. The narrative format can engage students and help them learn (Lowe, 2002). The narrative format may help organize the information and make it easier to process. Combining onscreen characters and an underlying narrative to present content as a story can be particularly effective.

Engagement seems to play a role in activating knowledge structures (Mayer 2005). As with other activation strategies, engagement seems to help activate existing schema (organizing structures) and create new schema. This makes it easier to absorb the new information and facilitate the transfer of knowledge from working memory to long term memory.

Multimedia learning is most effective when the learner can apply their newly acquired knowledge and receive feedback.

Multimedia is most likely to be effective when students are provided with opportunities to apply what they have learned following exposure (Mayer, 2005). This reinforces and strengthens the newly acquired knowledge. Students should be provided with opportunities to integrate what they have learned with their everyday life. Other strategies that help students integrate what they have learned include follow-up learning activities, class discussions and group activities.

Feedback is an important part of the learning process, and multimedia is no exception. It is important to provide learners with clear feedback about their progress on an ongoing basis (Gee, 2005; Perkins, 1992). Feedback helps keep students informed about their progress and helps them stay engaged (Gee, 2005). Providing feedback can reinforce what has been learned and can also correct any misconceptions. Feedback is most effective when it is frequent and immediate.

Both formal and informal feedback can support learning following multimedia exposure. Formal assessments (tests and quizzes) should be supplemented by in-process monitoring and comments from teachers. Multimedia applications that provide opportunities for student self-assessment offer a particularly valuable opportunity for feedback. Providing follow-up activities, graphic organizers and other supplemental learning opportunities that students can undertake on their own can also provide a basis for feedback.

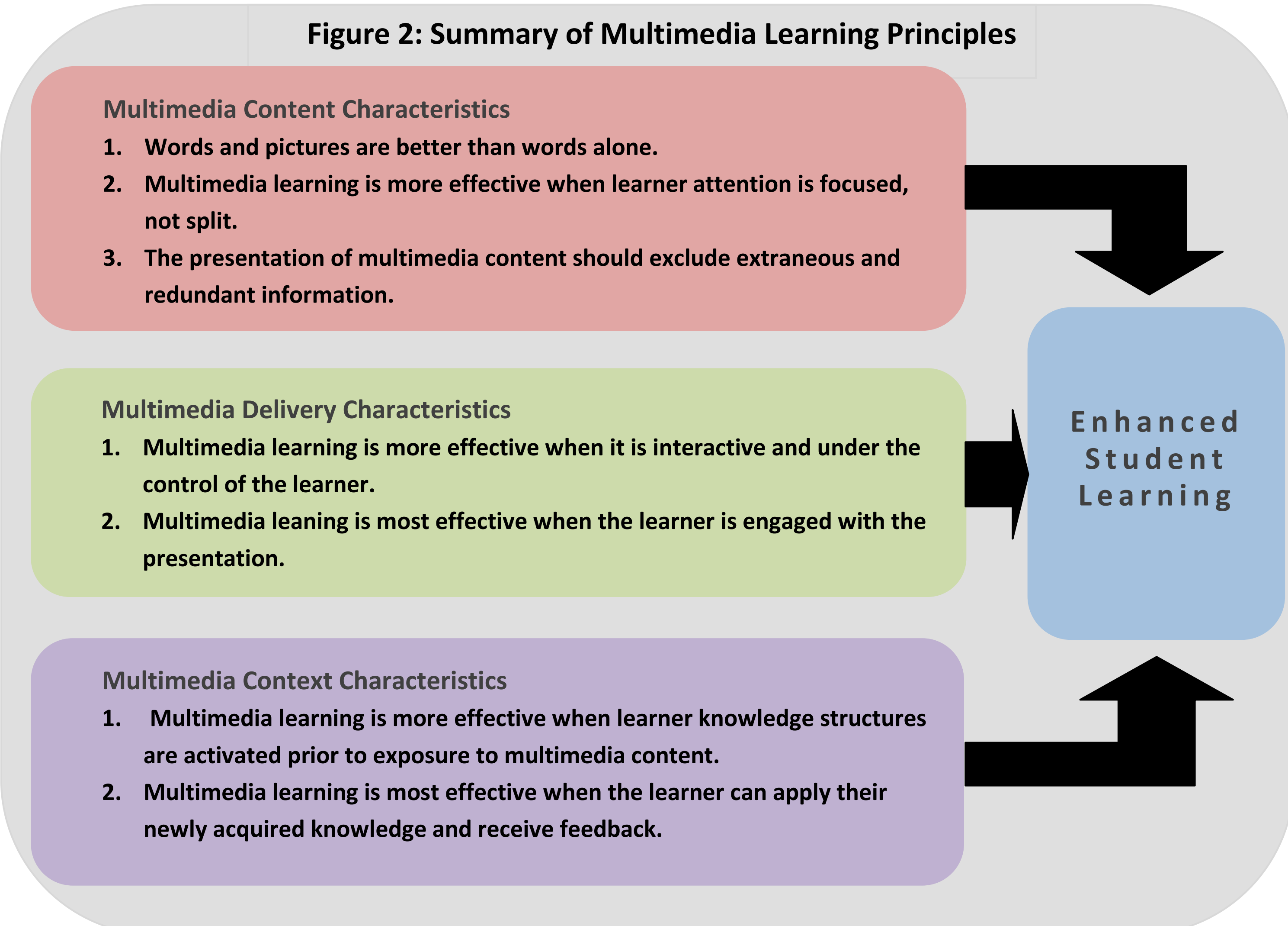

Figure 2: Summary of Multimedia Learning Principles

Individual learner differences and multimedia learning

As with any instructional tool, multimedia may work better for some students than others. There is a growing body of research showing that students learn in different ways and that information should be presented in different ways to engage students with differing learning styles.

"This research suggests that information should be presented in different ways to engage learners with different learning styles and strengths."

Howard Gardner and his colleagues at Harvard suggest that individuals can exhibit a wide range of abilities, and that intelligence is best thought of as multiple areas of expertise or as **multiple intelligences** (Gardner, 1993; Gardner 1999). Gardner suggests that there are eight distinct intelligences: linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal, intrapersonal and naturalistic. This information can be used to direct instruction toward students' strengths.

The perceptual learning styles model developed by Russell French, Daryl Gilley, and Ed Cherry (Institute for Learning Styles, 2008) in the late 1970s and early 1980s provides another useful way of viewing learner differences. This model proposes that learners extract information from their surroundings through the use of their senses and that there are seven pathways for learning: print, aural, interactive, visual, haptic, kinesthetic and olfactory.

This research suggests that information should be presented in different ways to engage learners with different learning styles and strengths. Students may have preferences for or learn most effectively through different modes. For example, one student may prefer or learn best from print, while another may prefer a more visual presentation of information. Multimedia learning may be particularly effective for visual and auditory learners.

Multimedia learning offers a significant opportunity to reach the greatest number of students and most effectively support students with different learning styles.

Conclusion

Including multimedia as part of instruction can significantly enhance student learning. Research has contributed much to our understanding of how the brain processes information, and we know that multimedia that recognizes how the brain processes information is more effective than multimedia that doesn't. This paper highlights several principles that discriminate between effective and ineffective multimedia use for teaching and learning. While multimedia learning technology is not a panacea, it should occupy a prominent place in the 21st century instructional toolbox, as research has shown it to be a significant tool for student engagement and learning.

Find out more

There is much written about multimedia learning. These two resources are an excellent starting place if you want to learn more.

Mayer, R.E. (2005) *The Cambridge Handbook of Multimedia Learning*. New York: Cambridge University Press.

Spector, J.M ., Merrill, M.D. Van Merrienboer, J., Driscoll, Marcy, P. (2008) *Handbook of Research on Educational Communications and Technology*. Third Edition. New York: Taylor Francis Group

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References

Baddeley, A. (1992) working memory. *Science*, 255,pp.556-559.

Baddeley, A. (1999) *Human memory*. Boston: Allyn and Bacon.

Betrancourt, M. (2005) The animation and interactivity principles in multimedia learning. In R. E. Mayer (Ed.). *The Cambridge Handbook of Multimedia Learning*. New York: Cambridge University Press.

Chandler, P,and Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction*, 8, pp.293-332.

Chi, M., Glaser R., and Rees, E. (1982) Expertise in problem solving. In R. Sternberg (Ed.) *Advances in the psychology of human intelligence* (pp.7-75) Hillsdale, NJ.: Erlbaum

Clark, R.E . and Feldon, D.F. (2005) Five common but questionable principles of multimedia learning. In R. E. Mayer (Ed.). *The Cambridge Handbook of Multimedia Learning*. New York: Cambridge University Press.

Craig, S.D., Gholson B., and Driscoll, D.M. (2002). Animated pedagogical agent in multimedia education environments: Effects of agent properties, picture features, and redundancy. *Journal of Educational Psychology*, 94, pp.428-434.

Gardner, H. (1993) *Frames of Mind: the theory of multiple intelligences*. New York: Basic Books.

Gardner, H. (1999) *Intelligence reframed: Multiple intelligences for the 21st Century*. New York: Basic Books.

Gee, J.P. (2005) :Learning by design: Good video games as learning machines, *E-Learning*. Vol.2 pp. 5-16.

Institute for Learning Styles (2008.) Overview of the seven perceptual styles. Retrieved August 28, 2008 from http://www.learning styles .org

Kalyuga, S. (2005) Prior knowledge principle in multimedia learning. In R. E. Mayer (Ed.). *The Cambridge Handbook of Multimedia Learning*. New York: Cambridge University Press.

Kalyuga, S.,Chandler, P. and and Sweller, J. (1999). Mnaaging splilt attention and redundancy in multimedia instruction. *Applied Congitive Psychomogy*, 13, pp.351-371.

Kolb, D. A., Boyatzis, R., & Mainemelis, C. (2001). Experiential learning theory: Previous research and new directions . In R. Sternberg and L. Zhang (Eds.) *Perspectives on cognitive learning, and thinking styles.* Mahwah, NJ: Erlbaum

Lee, J., Grigg, W., and Dion, G. (2007). *The Nation's Report Card: Mathematics 2007(NCES 2007–494).*National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education, Washington, D.C.

Lowe, K. (2002) *What's the story: making meaning in primary classrooms.* ERIC Document No. ED468691

Miller, (1956) The magic number of seven plus or minus two. Some limits on our capacity for processing information. *Psychological Review*; Vol, 63, 31-97.

Mayer, R.E. (2003*) Learning and Instruction*. Upper Saddle River, NJ: Prentice Hall.

Mayer, R.E. (2005) Introduction to multimedia learning. in R. E. Mayer (Ed.). *The Cambridge Handbook of Multimedia Learning*. New York: Cambridge University Press.

Mayer, R.E. (2005a). Principles of multimedia learning based on social cues: personalization, voice, and image principles. In R. E. Mayer, (Ed.) *The Cambridge Handbook of Multimedia Learning*. New York: Cambridge University Press.

Mayer, R.E. and Chandler, P. (2001) When learning is just a click away: Does simple interaction foster deeper understanding of multimedia messages? *Journal of Educational Psychology*, Vol. 93, pp. 390-397.

Mayer, R.E. and Sims, V.K. (1994) For whom is a picture worth a thousand words? Extensions of a dual-coding theory of multimedia learning. *Journal of Educational Psychology*, 86, pp.389-401

Mayer, R.E.,Sobko, K., and Mautone, P.D.(2003) Social cues in multimedia learning: role of speakers voice. *Journal of Educational Psychology*, 95, pp. 419-425.

Park, O. (1994). Dynamic visual displays in media-based instruction. *Educational Technology*, 21–25.

Perkins, D. (1992) *Smart Schools: Better thinking and learning for every child*. New York: The Free Press.

Pollock, E., Chandler, P., and Sweller J. (2002) Assimilating complex information. *Learning and Instruction*, 12, pp. 61-86.

Sweller, J. (2003) Evolution of human cognitive architecture. In B. Ross (Ed.), *The Psychology of learning and Motivation* (Vol. 43, pp.215-266). San Diego, CA: Academic Press.

Sweller, J. (2005) Implications of cognitive load theory for multimedia learning. in R. E. Mayer (Ed.). *The Cambridge Handbook of Multimedia Learning*. New York: Cambridge University Press.

Tversky, B., Bauer-Morrison, J., & Betrancourt, M. (2002). Animation: can it facilitate? *International Journal of Human-Computer Studies*, Vol 57, 247-262.