# Multimedia Learning Theories and Online Instruction

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Online library instruction has not traditionally been designed based on educational learning theories. Rather, much of it has been designed in the structure and format of print, with little thought given to the pedagogical approaches that support Web-based earning. Several relevant multimedia learning theories are surveyed in this article and compared with two versions of the same library tutorial—an HTML tutorial, and a streaming audio and video tutorial.

Formal programs of instruction for library users in higher education date from the 1970s, when the position of bibliographic instructional librarian became a necessity; the earliest programs included various modes of presentation, from traditional classroom teaching (lecture) to preprogrammed self-instructional materials. The latter were composed originally of print, but this form of instruction is now almost exclusively Web based. Most library instruction delivered via the Web is designed in the style and hierarchical structure of print, with little thought given to the pedagogical approaches supporting learning through Web-based instruction.[1] Very little online library instruction utilizes the full flexibility of the Web or employs a learner-centered, cognitive approach to multimedia learning.[2]

In the following pages, an HTML version and a streaming audio/video version of a library instruction tutorial will be compared. As all educational media differ from each other to varying degrees, HTML and streaming media provide a good framework for comparing and contrasting the multimedia learning theories that are the subject of this paper. The relevance of several cognitive learning theories to each version of the project are discussed. Table 1 lists the cognitive theories and principles presented in this paper and determines which tutorial version most closely follows each cognitive approach. Because the HTML How to Find an Article tutorial is indicative of the standard approach to designing and delivering library instruction, this paper also serves as a means of determining whether traditional online library instruction follows cognitive learning theories and provides opportunities for meaningful learning.

## Cognitive Load Theory and Instructional Design Approaches

Cognitive load theory (CLT) is concerned with providing a framework for instruction based on the assumption that the working memory's storage capacity is limited. Working memory is the area in which learners process and briefly store new information. Because working memory has a limited capacity, CLT

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**TABLE 1**
**Table head**

| *Principle/theory/Effect* | *HTML Tutorial* | *Streaming Media Tutorial* |
|---|---|---|
| Modality Effect | Not employed—only utilizes the visual processing channel, leading to potential cognitive overload, and less potential for meaningful learning. | **Information presented both visually and verbally, allowing for connections to be made between each channel, and meaningful learning to occur. Also allows for increased working memory storage capacity.** |
| Dual coding theory of multimedia | Not employed | **Employed** |
| Contiguity temporal and spatial | Employed—diagrams are in close proximity to text explaining them | Employed—narration and animation are presented simultaneously |
| Redundancy effect | Not applicable to this design | **No redundancy—presentation mode is limited to narration and animation—no on-screen text is employed** |
| Constructivism | **Navigation, while hierarchical, allows for choice. User not locked into learning environment as with video.** | Navigation, while hierarchical, allows for minimal choice. |
| Segmenting | No prescribed segmenting in this tutorial. | **Yes, after each step the user is presented with a transition screen providing a summary, worksheet, and ability to add notes.** |

**Highlighted text indicates favorable delivery mode for the principle/theory/effect.
The URL of HTML *How to Find an Article* tutorial: http://library.nyu.edu/research/tutorials/article/.
The URL of the Streaming media *How to Find an Article* tutorial: http://library.nyu.edu/research/tutorials/movie/article/.

proponents support instructional design that minimizes working memory load and utilizes the greater capacity of long-term memory. CLT instructional design approaches include: eliminating information that is not directly related to the learning task; chunking content so that it relates to long-term memory schema; and utilizing both processing channels in working memory in order to increase working memory storage.[3]

A goal of CLT instruction is to maximize meaningful learning potential. Meaningful learning occurs when connections are made between information in the visual- and the verbal-processing channels of working memory. Instruction that utilizes the two working memory modalities provides the learner an opportunity to create meaning between them, leading to schema connections and enhanced long-term memory utilization. Instruction that employs both working memory channels, such as coupling animation and narration, is a more effective delivery mode than coupling animation

with on-screen text, which utilizes only the visual-processing channel of working memory.[4] Richard Mayer's modality effect is an implication of Allan Paivio's dual-coding theory, which asserts that two processing channels can be used to enhance both recall and recognition when material is presented visually and verbally. According to Paivio and James M. Clark, "presenting pictures or telling students to generate images for pairs of words will prime the imagery system and increase likelihood that words will activate mental images."[5] Mental images contain detailed information linking temporary working memory storage to existing schema, stored in long-term memory. Mayer and Valerie K. Sims have adapted Paivio's dual-coding theory to create a dual-coding theory of multimedia, which asserts that "meaningful multimedia learning depends on building connections between mental representations of corresponding words and pictures."[6] These connections are created when mental integration between words and image representations are made.

Only one working memory processing channel is employed in the HTML How to Find an Article tutorial. Both text and images are processed through the visual channel. Visually presented text competes with images for cognitive processing in the visual channel. This creates unnecessary cognitive load and decreases the potential for mental connections to be made. The cognitive theory of multimedia learning follows the tenet that "the processes required for meaningful learning cannot be fully carried out when the visual channel is overloaded—that is, when pictures and printed words compete for limited cognitive resources in the visual channel because both enter the information processing through the eyes."[7]

In contrast, the proposed streaming version of the How to Find an Article tutorial utilizes both processing channels in working memory. Narration is processed through the verbal channel, and images are processed through the visual channel. This utilization of both processing channels in working memory provides the opportunity for learners to connect and create representations between each mode of information.[8] These mental connections lead to meaningful learning, defined as a "deep understanding of the material, which includes attending to important aspects of the presented material, mentally organizing it into a coherent and cohesive structure, and integrating it with relevant existing knowledge."[9]

### Contiguity Principle

Studies have shown that the provision of information that utilizes both processing channels in close proximity (or simultaneously) increases potential connections between the modalities.[10] This principle is called the contiguity principle, and it comprises both spatial and temporal contiguity. The spatial contiguity principle asserts that when images and text are provided close together, connections linking the two types of information will be made more easily and mental models leading to meaningful learning will occur. Not only does the close proximity of images and text allow for connections to be readily made, but this design also lessens cognitive load created by searching for supporting images that do not appear near the explanatory text. Unless both modalities are processed in working memory simultaneously, referential connections between them are less likely to be made, especially in inexperienced learners.[11]

The temporal contiguity principle asserts that if verbal and visual information are presented at the same time rather than with one representation following another, a higher rate of transfer to long-term memory will transpire.[12] Just as with spatial contiguity, where holding both mental and verbal images in the working memory at the same time leads to meaningful connections, by providing visual and verbal information simultaneously, mental connections leading to meaningful learning are more likely to occur.

The HTML of the How to Find an Article tutorial presents explanatory text immediately followed by a corresponding image, encouraging mental connections between them to be made. This simultaneous display of related diagrams and explanatory text allow for learning opportunities to occur.[13]

In accordance with the temporal contiguity principle, the narration in the streaming version of the How to Find an Article tutorial is presented simultaneously with corresponding screen capture video. As Mayer points out, "simultaneous presentations are designed to mesh with the human information processing system—including the availability of separate visual and verbal channels as well as the extreme limits on the capacity of each channel."[14] "Unlimited" storage is created when meaning and connections between the two modalities are linked to existing long-term memory schema.

### Cognitive Overload

Although working memory load is increased with instructional design that utilizes both processing channels described by the modality effect, the dual-coding theory, and the dual-coding theory of multimedia, cognitive overload can still occur. According to John Sweller and colleagues, even with text and images delivered in close proximity, unnecessary cognitive load may still be imposed if the images provide adequate explanation without the inclusion of text.[15] Information provided textually and visually is redundant for certain learners, and "if a learner has to expend limited resources on activities not directly related to schema construction and automation, learning may be inhibited."[16]

Another unnecessary cognitive load is the inclusion of redundant information that utilizes incidental processing. The redundancy effect occurs when animation, narration, and on-screen text are all provided in multimedia presentations. The learner must use his or her cognitive processing power to read and synthesize text with narration. This unnecessary task involves incidental processing, which reduces the ability to engage in essential processing.[17] Incidental processing should be kept to a minimum, despite the fact that it might improve understanding. Because cognitive processes involved in incidental processing are not necessary, however, they should be eliminated from the design. The possibility of unnecessary cognitive power being utilized for nonimperative learning, even by information that is useful, is not worth the associated risk of cognitive overload.

Because the HTML tutorial does not employ narration, there is no opportunity for the redundant effect—coupling narration with on-screen text—to take place. Inclusion of text in conjunction with graphics is necessary in this tutorial; without text, the graphics would not prove useful enough to stand alone as instruction.

The streaming tutorial does not engage in incidental processing; no music or information will detract form essential processing. The redundancy effect is not employed in this tutorial; the tutorial employs narration and animation but does not include on-screen text.

### Constructivism

Constructivists believe more in learner-constructed knowledge than they do designer-imposed instruction. Because each person has his or her own reality, the designer cannot determine how best to deliver instruction.[18] Because constructivists believe learners create their own external reality, they propose a highly flexible nonhierarchical design. This nonlinear approach to designing learning environments allows for the unlimited perspectives and realities of learners.

Learners who utilize library tutorials tend to be self-directed and highly motivated. This conclusion is based on the assumption that learners who elect to partake in nonrequired learning are motivated and independent. Because the design is intended for university students,

it can be assumed that most of its users are academically inclined. A beneficial learning approach for self-directed learners employs a constructivist model of learning. According to Kimbery Lawless and Scott Brown, when high-ability or highly experienced learners experience a very controlled instructional environment that is geared toward less-experience learners, they can be negatively impacted.[19]

The HTML How to Find an Article tutorial allows for some learner-controlled navigation and manipulation. However, a highly constructivist approach is not utilized in the design. Rather than allowing the learner to manipulate information to create his or her own learning construct, the author-imposed instructional hierarchy is always displayed. It is only within these confines that the learner is able to construct his or her own informational hierarchy.

The streaming version of the How to Find An Article tutorial employs a minimal constructivist approach in its design. Because the visual information is presented as video, the learner may feel "locked in" to the learning environment, even though he or she has the ability to pause, stop, or rewind the video at any point. The chunking of the video content into separate segments allows for some user flexibility, but like the HTML version, both tutorials proposed do not allow for unlimited learner flexibility and manipulation.

### Encouraging Active Learning with Interactivity and Segmenting

A major obstacle to effective learning is the instructional environment. One way to eliminate this constraint involves "segmenting a learning task so that it reduces load or enables the learner to manage the load more efficiently."[20] By providing time between each segment, the instructional designer affords the learner the ability to process the information at hand before proceeding. These pauses between sections of content represent good opportunities for providing interactivity, which further encourages and assists the learner in synthesizing and organizing information.

Interactivity is included in several steps of the tutorial in an effort to help promote learner-initiated connections. These interactive elements are designed to allow the user to reflect on the information delivered before moving to the next step in the learning process. The learner can select optional information to add to a printable worksheet. The selection of information to add to this worksheet encourages the user to organize and process the information. As well, this method is used to prevent working memory overload, which can occur when the learner must store information from one segment to another.

### Conclusion

Several multimedia learning theories have been surveyed in this paper and compared with two versions of the same tutorial. The first version (HTML) demonstrates the standard library instructional approach, with text and images included, and a hierarchical navigation bar with content organized in modules. The second demonstrates a less-traditional approach to library instruction that employs streaming audio and narration. According to the learning theories presented in this paper, the latter version is more effective as a teaching tool. This conclusion, and its underlying learning theories and principles, are summarized below.

## Notes

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2. Ibid.
3. Alexander Renkl and Robert Atkinson, "Structuring the Transition from Example Study

to Problem Solving in Cognitive Skill Acquisition: A Cognitive Load Perspective," *Educational Psychologist 38* no.15 (2003): 23.

4. Richard Mayer. *Multimedia Learning (Cambridge: Cambridge Univ. Pr., 2001), 135.*

5. James M. Clark and Allan Paivio, "Dual Coding Theory and Education," *Educational Psychology Review* 3, no.3 (1991): 155.

6. Richard Mayer and Valerie K. Sims, "For Whom Is a Picture Worth a Thousand Words? Extensions of Dual-coding Theory of Multimedia Learning," *Journal of Educational Psychology* 86, no.3 (1994): 389.

7. Ibid., 400.

8. Mayer, *Multimedia Learning*, 140.

9. Richard Mayer and Roxana Moreno, "Nine ways to reduce cognitive load in multimedia learning," *Educational Psychologist, 38,* no.1(2003):43.

10. Richard Mayer and Roxana Moreno, "Nine Ways to Reduce Cognitive Load in Multimedia Learning," *Educational Psychologist* 38, no.1 (2003): 43.

11. Richard Mayer and Richard Anderson, "The Instructive Animation: Helping Students Build Connections between Words and Pictures in Multimedia Learning," *Journal of Educational Psychology* 84, no.4 (1992): 444.

12. Ibid., 96–112.

13. Ibid., 96.

14. Ibid., 100–101.

15. Slava Kalyuga, Paul Ayres, Paul Chandler, and John Sweller, "The expertise Reversal Effect," *Educational Psychologist* 38, no. 1 (2003): 24.

16. Ibid.

17. Ibid.

18. Mary Driscoll, *Psychology of Learning for Instruction (Boston: Allyn and Bacon, 2005), 71.*

19. Kimbery Lawless and Scott Brown, "Multimedia Learning Environments: Issues of Learner Control and Navigation," *Instructional Science* 25, (2005): 117.

20. Rober Bruning, Gregory Schraw, Monica Norby, and Royce Ronning, *Cognitive Psychology and Instruction* (Upper Saddle River, N.J.: Pearson Merril Prentice Hall, 2003), 3.