

The Effects of Training, Modality, and Redundancy on the Development of a Historical
Inquiry Strategy in a Multimedia Learning Environment

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ABSTRACT

Research in the area of multimedia instruction has yielded results that indicate that learning is better when verbal information is presented auditorily instead of visually (i.e. modality effect) and when redundant on-screen text is removed from the instructional environment (i.e. redundancy effect). The present study aimed to extend these findings by exploring the effects of presentation modality and redundancy of verbal information on students' ability to apply and recall a historical inquiry strategy.

Fifty-six students were randomly assigned to three treatment groups, which differed according to the presentation mode combination used to present the strategy instruction. Specifically, students received the instruction either as animation and narration, animation and text, or animation, narration, and text. The students were engaged in a multimedia strategy intervention for a total of five days, for approximately 25 minutes a day. Three strategy application tests (i.e., pre-test, post-test, maintenance test) and a recall test were used to measure the students' learning.

Data attained through the strategy application tests and recall tests were analyzed using Analysis of Variance (ANOVA) procedures. The results of the study revealed significant differences in the training main effects analysis indicating that strategy instruction can be effectively provided in a multimedia learning environment. However, no significant differences were found for the modality and redundancy main effects indicating that there was no difference in strategy application or recall between the groups. Although the results did not provide the statistical significance that supports the literature on the modality and redundancy effects, the implications of the findings of the research provide several viable areas for future research.

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INTRODUCTION

Problem Presentation

The research surrounding the use of multimedia to deliver instruction has experienced significant change over the last several decades. Multimedia research that was once centered on the technologies used to deliver the presentation has shifted to a learner-centered approach that is grounded in theories of human learning (Mayer, 2001; Mayer & Moreno, 2002). Specifically, a focus has developed addressing the limited resource nature of working memory, dual-coding, and cognitive load and their implications on the design of multimedia instruction (Doolittle, McNeill, Terry, & Scheer, 2004).

The fundamental assumption behind this new focus is that working memory has separate systems for processing verbal and non-verbal information and experiences and that these systems are limited in overall processing capacity (Hodes, 1994; Mayer, 1997, 2001). An implication from this assumption is that the processing capacity of working memory can be increased by distributing information across both systems (Bruning, Schraw, & Ronning, 1999; Chandler & Sweller, 1991; Sweller, 1994). Accordingly, the capability of multimedia instruction to deliver information in both visual and verbal forms makes it a potentially powerful learning technology (Mayer, 2001).

If not designed appropriately, however, the “multi” in multimedia can increase the cognitive load on working memory and decrease learning (Chandler & Sweller, 1991; Kalyuga, Chandler, & Sweller, 1999). Cognitive load refers to the working memory demands imposed on the learner that are implicitly and explicitly created by the instruction (Doolittle et al., 2004). Consequently, cognitive load theory, which is

concerned with the way cognitive resources are focused and used during learning and problem-solving, has influenced the way many researchers and designers approach the design of multimedia instruction (Chandler & Sweller, 1991, 1992).

Richard Mayer and his colleagues have spent decades exploring the benefits and limitations of the verbal and visual processing systems in multimedia learning environments (see Mayer, 2001). This research has examined the effects of presentation modality, redundancy, contiguity, and coherence on students' understanding of scientific cause-and-effect explanations, which has yielded significant results and respective design principles. However, according to Mayer (1997; 1999), the results of this research are limited in that (a) the instruction focused solely on scientific cause-and-effect explanations and (b) the instructional presentations were short (i.e., less than 3 minutes) and system-paced.

The empirical findings by Mayer and his colleagues have offered instructional designers and practitioners numerous strong, theory-based principles for the design of multimedia instruction. However, research on learning from multimedia instruction is in its infancy (Mayer, 2001). These principles need to be tested on a range of learning outcomes and under a variety of conditions so as to understand the true potential of their implications. The present study represents a step in that direction as it attempts to extend previous findings from research on the modality and redundancy principles to a different learning outcome, namely, strategy development.

Overview

This study attempted to add to the literature that links various multimedia design principles to increased learning. Specifically, this study explored the effects of

presentation modality and redundancy on the development of a historical inquiry strategy. The study was situated in theories of human learning and models of strategy instruction and utilized an intervention based on the provision of strategy instruction via different multimedia attributes.

The study drew on a wide base of research on theories of human learning and models of effective strategy instruction. The range of literature that was reviewed includes the literature related to the cognitive architecture of the learner as it is situated within working memory models and dual-coding theory. Additionally, the study drew heavily on theories relating to the design of multimedia instruction, including cognitive load theory and the cognitive theory of multimedia learning. Finally, literature regarding the design of effective strategy instruction was reviewed in order to attempt to provide a sound basis from which to develop the strategy intervention.

This study seeks to uncover what effects strategy training (i.e., training), presenting information to both the visual and auditory sensory modalities (i.e., modality) and redundant verbal information (i.e., redundancy) have on the participants' ability to apply and recall a historical inquiry strategy. The intervention was designed according to guidelines for effective strategy instruction gleaned from the literature on learning strategies (Brown, Bransford, Ferrara, & Campione, 1983; Brown, Campione, & Day, 1981; Dehn, 1997; Gredler, 1997; Palincsar, 1986; Pressley et al., 1990). Ultimately, it is hoped that the results of this study will extend the previous research findings on the effectiveness of multimedia applications to the development of cognitive strategies.

Definition of Terms

For the purpose of this study, a number of psychological and theoretical terms are defined in order to provide for greater understanding of concepts and relationships of concepts within the literature review.

Cognition: thought processes; inner thought processes by which we incorporate information into our stored knowledge base (Jacobson, 1998).

Cognitive load: multidimensional construct that refers to the working memory load that performing a task imposes on the learner (Paas & van Merriënboer, 1994).

Expert: individual with a depth of understanding in a given domain who can reliably perform specific observable behaviors relevant to a task within the domain (Jacobson, 1998).

Multimedia: presentation of information via more than one sensory modality and/or presentation mode through some form of communication device.

Presentation mode: refers to the format used to represent the presented instruction, such as words vs. pictures (Mayer, 1997).

Redundancy: refers the presentation of written verbal information (i.e., on-screen text) that is identical to spoken verbal information (i.e., narration) in multimedia instruction.

Sensory modality: refers to the information processing channel that a learner uses to process information such as auditory vs. visual information processing (Mayer, 1997).

Strategies: tools or methods available to the learner that can be used to accomplish a goal; *cognitive* strategies are skills that allows learners to select and guide the internal processes involved in thinking and learning (Gagne, 1984); *metacognitive*

strategies are used for allocating, monitoring, coordinating, and adjusting internal processes/resources (Mayer, 2001).

REVIEW OF LITERATURE

This review of literature is divided into four sections. The first section discusses the theoretical framework that serves as the foundation for multimedia learning. The second section of the review discusses developments in the study of multimedia and the resulting design principles. The third section is focused on strategies and criteria for successful strategy interventions. Finally, the last section provides a synthesis of the previous sections with a focus on the implementation of strategy instruction in a multimedia learning environment.

Theoretical Framework

According to Doolittle, McNeill, Terry, and Scheer (2004) “the domain of multimedia has matured beyond technology-driven applications into the realm of cognition and instruction” (p. 185). The focus in multimedia instruction that was once centered on the capabilities of the technology has shifted to what should be done with technology in order to design meaningful instruction (Rouet, Levonen, & Biardeau, 2001). This shift in focus has involved the integration of learner cognition, instructional design, and instructional technology with much of this integration focusing on the role of working memory in the development of comprehension and performance (Doolittle et al., 2004).

Specifically, a focus has developed addressing the limited resource nature of working memory, dual coding, and cognitive load. The relationship between these three factors has proved to be especially significant when the instruction is in the form of multimedia (Doolittle et al., 2004). Therefore, the following sections highlight key tenets

of the working memory model, dual-coding theory, and cognitive load theory in an effort to explain their impacts on the design of multimedia instruction.

Working Memory

In an effort to ground the design of multimedia instruction in theories of human learning, it is important to begin with a focus on the structure and function of the human memory system. The two most prevalent memory models are Atkinson and Shiffrin's (1968) dual-store model and Baddeley's (1986) working memory model.

Atkinson and Shiffrin (1968) proposed a dual-store, multi-stage theory of memory (Driscoll, 2000). This theory proposes that information goes through a series of transformations from the moment it is received until it is permanently stored in long-term memory. The resulting model came to be known as the *modal model* (Atkinson & Shiffrin, 1968), and suggests that there are three independent structures of the human memory system (i.e., sensory memory, short-term memory, and long-term memory).

According to Atkinson and Shiffrin (1968) information processing begins in *sensory memory* where information is received from environmental inputs and held briefly in sensory registers until the information is either recognized or lost. While all information is registered by the sensory registers, only stimuli that are attended to will be sent to *short-term memory* for further processing. Two important aspects of short-term memory commonly agreed upon at the time include its short duration and limited capacity (Driscoll, 2000). Consequently, the longer an item (i.e., piece of information or experience) is held and rehearsed in the short-term memory store, the greater chance it has of being transferred to *long-term memory*.

The dual-store of Atkinson and Shiffrin's (1968) model refers to the short-term memory store, where limited amounts of information can be held for a brief period of time, and the long-term memory store, where an unlimited amount of information can be held indefinitely. According to Baddeley (1998) this dual-store model proposed by Atkinson and Shiffrin "represents the high-water mark of two-component or dichotomous models of memory" (p. 45). By the early 1970's, further testing of the dual-store model indicated that concrete evidence for two separate storage components was sparse (Baddeley, 1992). Consequently, by the end of the 1980's the dual-store model was being replaced by a unified working and long-term memory model (Doolittle et al., 2004).

As a result of the observed difficulties with the Atkinson and Shiffrin dual-store model, Alan Baddeley conducted a series of studies to test the widely held assumption that short-term memory "acts as a temporary working memory that helps us perform a range of other cognitive tasks" (Baddeley, 1998, p. 50). The result of his efforts was a new model of human memory known as the *working memory model*, which is comprised of three components: a supervisory control system, the *central executive*, supplemented by two slave systems, the phonological loop and visuo-spatial sketchpad.

The *central executive* system governs what enters working memory, selects strategies necessary to process information, and controls and coordinates information from the two slave systems (Bruning et al., 1999). It is suggested that the effective use of working memory depends on the degree to which the central executive can direct this cognitive activity in an automatic fashion. The central executive is assisted by the operation of the two slave systems, the phonological loop and the visuo-spatial sketch pad.

The first slave system, the *phonological loop*, is specialized for the storage of verbal information for short periods of time (i.e., 2-4 seconds). This system is comprised of two main components: (1) a phonological store that is capable of holding speech-based information for about two seconds and, (2) an articulatory control process that is analogous to inner speech (Baddeley, 1986, 1992). The loop serves to maintain information in the phonological store by subvocal repetition and has the capability of taking visually presented information, such as words or nameable pictures, and registering them in the phonological store (Baddeley, 1986).

The second slave system, the *visuospatial sketchpad*, is specialized for “the processing and storage of visual and spatial information, and of verbal material that is subsequently encoded in the form of imagery” (Gathercole & Baddeley, 1993, p. 17). This system is responsible for setting up and manipulating visual and spatial images and can take in information directly through visual perception or indirectly through visual imagery.

An assumption surrounding each of the subsystems in the working memory model proposed by Baddeley (1986) is that each possesses its own limited attentional resources. Under normal information processing demands, each subsystem can perform mental work without taxing the resources of the remaining subsystems (Bruning et al., 1999). Therefore, overall working memory capacity can be increased provided the information is distributed over the two subsystems.

Ultimately, the concept of working memory has replaced the older concept of short-term memory (Baddeley, 1992). While working memory has retained certain short-term memory characteristics (e.g., limited capacity), the two are significantly different.

Specifically, the two memory structures (i.e., short-term memory and working memory) differ in the following ways (Doolittle et al., 2004):

- Short-term memory was construed as a *location* for storing information while working memory is defined as a set of *cognitive processes* responsible for the support of complex cognition.
- Short-term memory is described as *subservient* to long-term memory whereas working memory is interpreted as working *synergistically* with long-term memory.
- The relationship between short-term and long-term memory is one of *independence* whereas the relationship between working memory and long-term memory is one of *interdependence*.

The working memory model depicts what happens to information after it is perceived by the sense organs and suggests that there are separate systems (i.e., visuospatial sketchpad and phonological loop) for processing visual and verbal information. Dual-coding theorists build on this idea of separate channels for visual and verbal information as well as the synergistic, interdependent relationship between working memory and long-term memory. The following section further explores this dual-coding aspect of memory.

Dual-Coding Theory

Paivio (1990) created a theory of cognition that emphasizes the mind's processing of two types of information that are represented in functionally independent, but interconnected processing systems (see Figure 1). One system, the *nonverbal system*, is specialized for the representation and processing of nonverbal information (e.g., pictures,

sounds, tastes), while the other system, the *verbal system*, is specialized for the representation and processing of verbal information (e.g., words, sentences, stories).

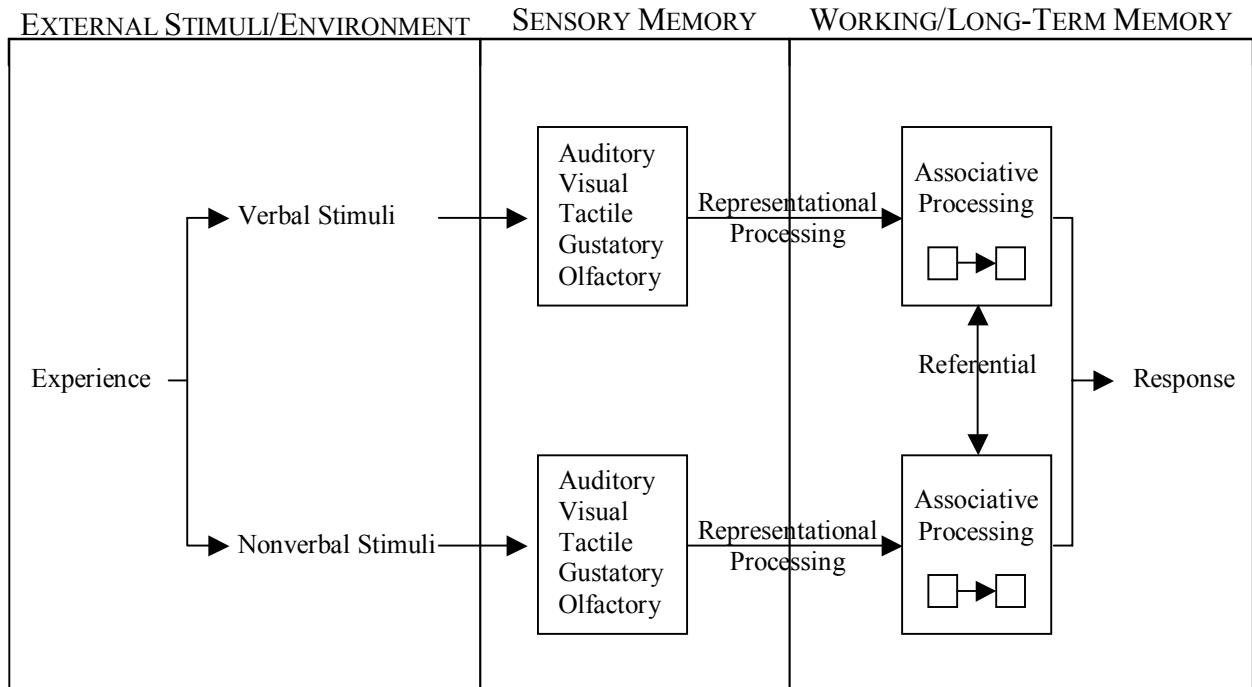


Figure 1. A schematic representation of Paivio's (1990) dual coding model including both verbal/nonverbal channels and representational, associative, and referential processing.

The *nonverbal system* (i.e., imagery system) contains modality-specific images for shapes, sounds, actions, and other nonlinguistic objects and events. Exactly how the system operates to store this information is not known, however dual code theorists agree that mental images are not exact copies of the visual information perceived. Instead, images tend to be imprecise representations with many details omitted, incomplete, or inaccurately recorded (Driscoll, 2000). The *verbal system* contains visual, auditory, articulatory, and other modality-specific verbal codes. These codes retain their discrete identities and are generally processed serially or sequentially (Clark & Paivio, 1991).

The two systems are assumed to be *structurally* and *functionally* independent. *Structurally*, the systems differ in the nature of representational units and the way they are organized. The structural representations refer to information in long-term memory corresponding to perceptually identifiable objects and activities, both verbal and nonverbal. *Functionally*, the systems are independent in that either system can be active without the other or they can work in tandem. Although the verbal and imagery systems are structurally and functionally different, they are interconnected in that information represented as an image in the imagery system can be converted to a verbal label in the verbal system, and vice versa (Klatzky, 1980).

According to Paivio (1990), three levels of processing enable verbal and nonverbal representations to be accessed and activated to be used in cognitive tasks (see Figure 1). *Representational processing* is the relatively direct activation of a verbal code by linguistic, or speech-based, stimuli and a non-verbal code by non-linguistic stimuli. In other words, someone talking or reading text is going to activate the verbal system while seeing a picture or hearing a sound is going to activate the non-verbal system. *Referential processing* refers to the activation of the non-verbal system by verbal stimuli and activation of the verbal system by non-verbal stimuli. Imaging to words and naming objects are two common examples of this type of processing. Consequently, referential processing is indirect in nature because it requires cross-over activity from one symbolic system to another. Finally, *associative processing* refers to the activation of representations within either system by other representations or codes within the same system.

One of the first insights associated with dual-coding theory was the role of nonverbal, imaginal processes in learning and memory tasks (Clark & Paivio, 1991). The predicted mnemonic benefits of imagery processes were explained in terms of two imagery based processes: elaboration and organization. The elaborative or “dual coding” explanation for imagery effects states that the additive effect of imagery and verbal codes is better than a verbal code alone (Paivio, 1975).

Further support for a dual-coding model came from research where learners were given instructions to form images while reading instructional text. The results showed that generating images produced better recall than repeating encoding conditions (i.e., repeating words aloud or silently) and better memory than deep encoding operations such as translating to another language or generating synonyms (Clark & Paivio, 1991).

In addition to being instructed to image while performing some cognitive task, another important determinant of imagery processing is the nature of the material being studied (Paivio, 1990). Both imagery and concreteness play an important role in memory for text. Concrete verbal information is remembered better than abstract text. This is assumed to occur because concrete verbal information is more easily imaged, thus they have the capability of being represented in both systems, rather than the verbal system alone. However, words that can be imaged are not necessarily imaged automatically. Consequently, it is believed that pictures should be more memorable than text because they tend to be automatically labeled and hence dual coded (Paivio, 1990).

It is suggested that memory is superior for imaged information since it is thought to have two representations in long-term memory. Imagery, which is generated internally, is the result of information processing. Consequently, the same limits exist in

imaginal processing as are seen throughout the information processing model (Burton, Moore, & Holmes, 1995). Due to the limited processing capacity of working memory, information processing and imagery processing can deteriorate when dealing with large quantities of information.

In summary, dual-coding theory suggests that individuals have two separate systems for representing verbal and nonverbal information. These systems are structurally and functionally independent; however, they are also interconnected. It is assumed that imaged information has two representations in long-term memory thus increasing its chance of retrieval. Studies that have examined the verbal and non-verbal processing systems have revealed two central findings (Mayer, Heiser, & Lonn, 2001; Sadoski & Paivio, 2001): (a) processing information verbally and visually leads to greater learning, retention, and transfer than processing information only verbally and (b) both verbal and visual channels of information processing are subject to memory limitations such that each channel may be overloaded. These findings have implications for the design of multimedia instruction and are explored further in the next section, which addresses cognitive load.

Cognitive Load Theory

The preceding sections highlighted the assumptions that the information processing system is comprised of two independent channels for processing and representing information, which are limited in their capacity. When designing instruction, it is important to keep these factors regarding basic human cognitive architecture in mind. However, researchers (Chandler & Sweller, 1991; Sweller & Chandler, 1994) have pointed to cognitive load theory to suggest that many instructional

procedures do not account for working memory limitations, thus, rendering them ineffective because they impose a heavy cognitive load.

Cognitive load is a multidimensional construct that refers to the memory load that performing a task imposes in the learner (Paas & van Merriënboer, 1994; Sweller, van Merriënboer, & Paas, 1998). *Cognitive load theory* is concerned with the way cognitive resources are focused and used during learning and problem-solving and is inextricably linked with the notion that working memory is a limited resource (Chandler & Sweller, 1991, 1992). Further, cognitive load theory is based on several assumptions concerning human cognitive architecture (Mousavi, Low, & Sweller, 1995), including the following:

- People have limited working memory capacity and processing capabilities.
- Long-term memory is virtually unlimited in size.
- Schema acquisition is a primary learning mechanism.
- Automation of cognitive processes decreases working memory load by essentially bypassing it.

Ultimately, the central premise of cognitive load theory is that working memory is limited and, if overloaded, learning will be adversely affected.

Cognitive load theory posits that instructional materials impose upon the learner three independent sources of cognitive load: *intrinsic cognitive load*, *extraneous cognitive load*, and *germane cognitive load* (Gerjets & Scheiter, 2003; Paas, Renkl, & Sweller, 2003). Together, intrinsic, extraneous, and germane cognitive load comprise the total working memory load imposed on the learner during instruction (Chandler & Sweller, 1991; Sweller, 1994; Sweller et al., 1998; Tindall-Ford, Chandler, & Sweller, 1997).

Intrinsic cognitive load represents the working memory load required to complete a task. This load is inherent within the given task and, thus, is beyond the direct control of the instructional designer. Sweller (1994) suggests that the amount of interaction between learning elements (i.e., element interactivity) is a critical factor influencing intrinsic cognitive load. Element interactivity occurs when the “elements of a task interact in a manner that prevents each element from being understood and from being learned in isolation and, instead, requires all elements to be assimilated simultaneously” (Tindall-Ford et al., 1997, p. 260). For example, learning the syntax of a language imposes a heavy intrinsic cognitive load because to learn word orders, all the words must be held in working memory simultaneously.

What constitutes an element does not depend solely on the nature of the material, but it also depends on the expertise of the learner (Tindall-Ford et al., 1997). High element interactivity may not result in high cognitive load if expertise has been attained, thus allowing the learner to incorporate multiple elements into a single element through schema acquisition and automaticity. This is evidenced when considering novice readers versus expert readers. For novice readers, each letter in a word may constitute an element, however, for expert readers, entire words or groups of words will have been incorporated into schemas that act as an independent element. Thus, the act of reading may result in extremely high intrinsic cognitive load for novices while not imposing any cognitive load on expert readers.

In addition to intrinsic cognitive load, the manner in which information is presented to the learners and the activities that are required can impose additional cognitive load (Paas et al., 2003). While intrinsic cognitive load is determined by the

nature of the material, *extraneous cognitive load* reflects the effort required to process poorly designed instruction. Extraneous cognitive load represents the core of cognitive load theory and is under complete control of instructional designers (Sweller et al., 1998). Essentially, poorly designed instruction can impose heavy working memory demands that adversely affect performance.

The remaining type of cognitive load is *germane cognitive load*. Germane cognitive load is the cognitive load appropriated when an individual engages in processing that is not designed to complete a given task, but rather, is designed to improve the overall learning process (e.g., elaborating, inferring, or automating). Engaging in processes that generate germane cognitive load is only possible when the sum of intrinsic and extraneous cognitive load is less than the limits of an individual's working memory. In addition, like extraneous cognitive load, germane cognitive load is influenced by the instructional designer. The manner in which information is presented to learners and the learning activities required of learners are factors relevant to the level of germane cognitive load. However, while extraneous cognitive load interferes with learning, germane cognitive load enhances learning by devoting resources to such tasks as schema acquisition and automation (Paas et al., 2003)

Together, intrinsic, extraneous, and germane cognitive load represent the total amount of working memory load that is present during instruction (Chandler & Sweller, 1991; Sweller, 1994; Sweller et al., 1998). While the instructional designer cannot control the amount of element interactivity that is inherent in instructional materials, he or she can directly influence the amount of extraneous cognitive load and germane cognitive load experienced by the learner. Several factors related to the way in which instruction is

designed can increase extraneous cognitive load, including split-attention, redundancy, and presentation modality.

Instructional materials often require students to split their attention among and mentally integrate multiple sources of information before meaning can be derived, thus producing a *split-attention effect* (Sweller & Chandler, 1994; Sweller et al., 1998; Tindall-Ford et al., 1997). Cognitive load theory has been used to explain why studying worked examples can be, at times, more effective in facilitating learning than conventional problem-solving approaches (Chandler & Sweller, 1991).

According to Sweller, Chandler, Tierney, and Cooper (1990) an essential ingredient of problem-solving skill is schema formation, where a schema is defined as a “mental construct permitting problem solvers to categorize problems according to solution modes” (p. 176). They suggest that conventional problem-solving procedures (e.g., means-end analysis) often result in students attending to inappropriate aspects of a problem from the point of view of schema acquisition, which imposes a heavy cognitive load. In contrast, worked examples direct the learners’ attention to aspects of the problem that are important to learning and facilitate the process of schema acquisition (Sweller, 1994).

However, alternatives to conventional problem-solving procedures, such as worked examples, are only likely to be useful if they do not impose a heavy cognitive load. Many worked examples consist of a diagram with an associated set of statements that may be totally meaningless in isolation. Ultimately, the multiple sources of information must be mentally integrated before any meaning can be derived. This split-attention effect imposes a heavy load on working memory.

In addition to worked examples, many introductory explanatory materials also combine text and diagrams. These separate sources of information are often unintelligible if they are not mentally integrated. Consequently, mental integration is likely to be cognitively taxing whether required for a worked example, for initial instruction, or for any other type of instructional material. Ultimately, the split-attention effect is general in nature and may apply to any instruction requiring mental integration of disparate sources of information (Chandler & Sweller, 1992).

In an effort to alleviate the split-attention effect it was suggested that all disparate sources of information should be physically integrated so that learners are not performing unnecessary mental integrations that interfere with learning. Sweller et al. (1990) tested this hypothesis by presenting students with coordinate geometry instructions in either a split-source format (i.e., conventional format) or in a unified format. The “split-format” group was presented instructions in which a geometry diagram and the corresponding textual information describing the diagram were separated. The “unified” group received the same instructions but the diagram and corresponding textual information were integrated. The results indicated that students receiving the unified diagrams and instructions performed better with respect to both solution time and problem solution. The researchers concluded that eliminating the split-attention effect, by integrating the diagrams and text, reduced cognitive load by allowing students to form schemata without having to first rework the material (Sweller et al., 1990). However, it was noted that the results of this study should *not* be used to assume that all diagrams and text should be integrated.

A *redundancy effect* can occur under circumstances where disparate sources of information that are intelligible in isolation are physically integrated. Chandler and Sweller (1991) found evidence for a redundancy effect when they presented students with a fully labeled and descriptive diagram depicting blood flow through the heart, lungs, and body. For most students, the diagram was self-explanatory with the associated text (e.g., “Blood from the lungs flows into the left atrium”) being redundant. In this situation, each source of information is fully intelligible and integration was not necessary for learning to occur. Ultimately, it was found that processing redundant information imposed another form of extraneous cognitive load, which can be reduced if redundant material is removed, not integrated (Chandler & Sweller, 1991, 1992).

Evidence derived from the split-attention effect and the redundancy effect has provided implications for designing instruction that aims to decrease the burden on working memory by eliminating the need to mentally integrate disparate sources of information and removing redundant information. Another approach taken by cognitive load theorists is to attempt to decrease cognitive load by increasing the capacity of working memory. It is suggested that obstacles associated with working memory limitations can be ameliorated by using dual-modality techniques (Mousavi et al., 1995).

The *modality effect* indicates that learning is better when verbal information that must be integrated with visually presented information (e.g., diagram) is presented in an auditory (i.e., spoken words) rather than visual (i.e., written words) mode (Mousavi et al., 1995; Sweller et al., 1998; Tindall-Ford et al., 1997). The rationale behind the modality effect is that when verbal information is presented auditorily (i.e., narration) rather than

visually (i.e., on-screen text), cognitive load is decreased because the work is spread over both the visual and auditory processing systems.

Mousavi et al. (1995) tested for the modality effect using geometry instructions. The researchers argued that if working memory limitations were the cause of the split-attention effect, then increasing working memory by presenting information to both visual and auditory sensory modalities, instead of purely visual form, would be beneficial. The results indicated that a visually presented geometry diagram, coupled with statements presented auditorily, enhanced learning compared to conventional visual-only presentations.

Tindall-Ford et al. (1997) also found evidence of the modality effect in experiments using electrical engineering instructional materials. However, the researchers also distinguished between material that was either low or high in element interactivity. The first experiment demonstrated that when two sources of information must be mentally integrated it is better to present the text in an auditory form, unless the diagram and text could be physically integrated. The results of the second experiment, which used information that was high in element interactivity, also demonstrated the superiority of presenting information to both the visual and auditory modalities.

In summary, the construct of cognitive load is a means for assessing working memory limitations and for understanding the beneficial effects of presenting information both visually and auditorily. By considering all the factors that may place undue burden on the working memory system of the learner while engaged in a cognitive act, designers can develop multimedia presentations that will promote learning. The following section presents additional multimedia research based on this understanding of human learning.

Multimedia

Until recently, the term multimedia was used to refer to the use of multiple media devices in a coordinated fashion (Moore, Burton, & Myers, 1996). However, advances in technology have combined these media so that information previously delivered by several devices can now be integrated into one device: the computer (Kozma, 1994). Thus, multimedia can be defined as the integration of more than one medium into some form of communication. Most often, “multimedia refers to the integration of media such as text, sound, graphics, animation, video, imaging, and spatial modeling into a computer system (vonWodtke, 1993)” (as cited in Jonassen & Reeves, 1996, p.703).

Most definitions of multimedia emphasize the *presentation* of multiple media with the computer playing a central organizing role. Early research on multimedia design focused on capturing the capabilities of new media devices to deliver instruction. However, the focus of multimedia instruction has shifted away from this technology centered approach to a more learner centered approach, where the emphasis is on how to design multimedia to aid human cognition (Mayer, 2001). This shift in focus highlights the importance of a solid foundation in learning theory when investigating the effects of multimedia on learning and performance.

The following sections focus on aspects of learning theories that have guided recent investigations of multimedia learning. These theories emphasize the structure, function, and limitations of working memory and how people process and learn verbal and visual material.

Case for Multimedia Learning

Words and pictures comprise the two main formats available for presenting instruction. Words, or verbal information, include speech or printed text, whereas pictures, or nonverbal information, include static graphics (e.g., illustrations and photos) and dynamic graphics (e.g., animation and video). In most traditional instructional settings, the most common format for presenting instruction has been printed and spoken words (Mayer, 2001). Consequently, this form of presentation and learning guided early educational research.

However, advances in computer technology resulted in the emergence of numerous ways to present visual material. This allowed designers to combine words and pictures in ways that were not previously possible. New questions emerged concerning the effectiveness of presenting instruction in both words and pictures. Ultimately, researchers wanted to know how multimedia could be used to increase learning.

The case for multimedia learning is based on the premise that instruction should be designed according to how the human mind works (Mayer, 2001). Accordingly, research has provided strong evidence that humans have two independent but interconnected systems for processing and representing verbal and nonverbal information (Baddeley, 1986, 1992, 1998; Clark & Paivio, 1991; Paivio, 1990). The rationale for using multimedia presentations is that the capability exists to take advantage of the dual channel processing system of the learner, which allows the learner to build connections between visually and auditorily presented material.

Before turning to the theoretical framework that has guided recent research on multimedia effectiveness, three views of multimedia instruction are discussed.

Multimedia can be viewed in terms of the delivery media, the presentation modes, or the sensory modalities operating during instruction.

The *delivery media view* emphasizes the delivery devices (e.g., computer screens, projector, speakers, etc.) used to present to material. This view focuses on the physical system or devices used to present the instruction rather than on how people learn.

The *presentation modes view* emphasizes the presentation modes (e.g., words and pictures) used to present the material. This view is learner centered and is consistent with a cognitive theory of learning, which assumes that humans have separate information processing channels for verbal and pictorial knowledge (Mayer, 2001). Paivio's dual-coding theory (Clark & Paivio, 1991; Paivio, 1990) represents theoretical and empirical evidence for this view.

The *sensory modalities view*, also learner centered, emphasizes the sensory systems involved in perceiving the information. This view focuses on the sensory receptors (e.g., eyes and ears) used to perceive incoming information. It is also based on the assumption that humans have separate visual and auditory processing systems. Baddeley's working memory model (Baddeley, 1986, 1992, 1998) provides the theoretical and empirical support for the sensory modalities view.

The delivery media view of multimedia results in a technology-centered approach to multimedia design. The well known "media comparison studies" were based on a technology-centered approach that focused on cutting-edge technologies instead of promoting learner understanding (Hannafin & Rieber, 1989). In recent years, this approach has been replaced by learner-centered approaches to multimedia design, which support the presentation modes view or sensory modalities view of multimedia. The

following section presents a theoretical framework that is based on this learner-centered approach.

Cognitive Theory of Multimedia Learning

Richard Mayer and his colleagues have conducted extensive research exploring the benefits and limitations of the visual and auditory processing systems in multimedia learning (Mayer & Anderson, 1991, 1992; Mayer, Bove, Bryman, Mars, & Tapangco, 1996; Mayer & Chandler, 2001; Mayer & Gallini, 1990; Mayer et al., 2001; Mayer & Moreno, 1998, 2002; Mayer, Moreno, Boire, & Vagge, 1999; Moreno & Mayer, 1999, 2000, 2002). Mayer focuses on the auditory/verbal channel and the visual/pictorial channel, defining multimedia as “...the presentation of material using both words and pictures....I have opted to limit the definition to just two forms-verbal and pictorial- because the research base in cognitive psychology is most relevant to this distinction” (Mayer, 2001, pp. 2-3). Most of Mayer’s work is based on an integration of three theories: Baddeley’s *working memory model* (Baddeley, 1986, 1992, 1998), Paivio’s *dual-coding theory* (Clark & Paivio, 1991; Paivio, 1990; Sadoski & Paivio, 2001), and Sweller’s *cognitive load theory* (Chandler & Sweller, 1991; Sweller, 1994; Sweller & Chandler, 1994).

Based on these three theories, Mayer has proposed a *cognitive theory of multimedia learning* (see Figure 2). This model is premised on the following three assumptions:

1. *Dual channels*: humans possess separate channels for processing verbal and nonverbal information.

2. *Limited capacity*: each channel is limited in the amount of information it can process.
3. *Active processing*: dual channel processing is an active cognitive process designed to construct mental representations with other knowledge.

The *dual channel assumption* holds that individuals have separate channels for processing verbal and nonverbal information. This assumption is consistent with the working memory model (Baddeley, 1986, 1992, 1998) and dual-coding theory (Clark & Paivio, 1991; Paivio, 1990). The differences in the channels can be conceptualized in two ways: presentation modes view and sensory modalities view.

The presentation modes view focuses on the stimuli used to present the material, for example, whether it is through words or pictures. This view is most consistent with Paivio's (1990) distinction between the verbal and nonverbal systems where one channel processes verbal information and the other channel processes nonverbal information. On the other hand, the sensory modalities *view* is based on how the learner initially processes the presented information, for example, whether it is through the eyes or ears. This view is consistent with Baddeley's (1986, 1992) working memory model where the phonological loop deals with verbal information and the visuospatial sketchpad deals with visual and spatial information.

Each channel is distinct and has its own processing responsibilities. However, the channels are interconnected. Information that is initially processed in one channel may be converted and processed in the other channel. For example, onscreen text is presented visually to the eyes initially leading to the information being processed by the verbal channel. However, the learner may be able to convert the text into sounds which are then

processed in the nonverbal channel. Similarly, a learner who is presented an image of a schoolhouse will initially process the image in the nonverbal channel, but will also be able to construct the verbal label in the verbal channel. Conversely, a narration describing an object or event such as “a quarterback throwing the game winning touchdown” will initially be processed in the verbal channel after being presented to the ears, but the learner may easily form a mental image of the event in the nonverbal channel. This referential processing plays an important role in Paivio’s (1990) dual-coding theory and Mayer’s (2001) cognitive theory of multimedia learning.

The *limited capacity assumption* builds on the premise that humans are limited in the amount of information that can be processed in either channel at one time. For example, when presented an illustration or animation, the learner is able to hold a few images in working memory at a time. The images are not exact copies of the material, but instead represent portions of the presented information. Similarly, when presented a narration, the learner is only able to hold a few words in working memory at any one time. Again, these words are only portions of the presented text, not verbatim recording. This limited capacity assumption is consistent with Baddeley’s (1986, 1992, 1998) working memory model and Sweller’s (1994) cognitive load theory.

The *active processing assumption* forms the final assumption underlying the cognitive theory of multimedia learning. This assumption posits that humans actively engage in cognitive processing by selecting relevant information, organizing the information into a coherent representation, and making connections between corresponding representations in each store (Mayer, 1997). According to Mayer (2001),

the outcome of active processing “is the construction of a coherent mental representation, so active learning can be viewed as a process of model building” (p. 51).

The aforementioned assumptions form the building blocks of the *cognitive theory of multimedia learning* (see Figure 2). According to this theory, the learner must engage in the following five cognitive processes in order for meaningful learning to occur (Mayer, 2001):

- (1) Selecting relevant words for processing in verbal working memory
- (2) Selecting relevant images for processing in visual working memory
- (3) Organizing selected words into a verbal mental model
- (4) Organizing Selected images into a visual mental model
- (5) Integrating verbal and visual representations as well as prior knowledge.

It is important to note that this process is iterative in nature and requires the learner to coordinate and monitor the processes during learning. Details of each step in the cognitive theory of multimedia learning follow.

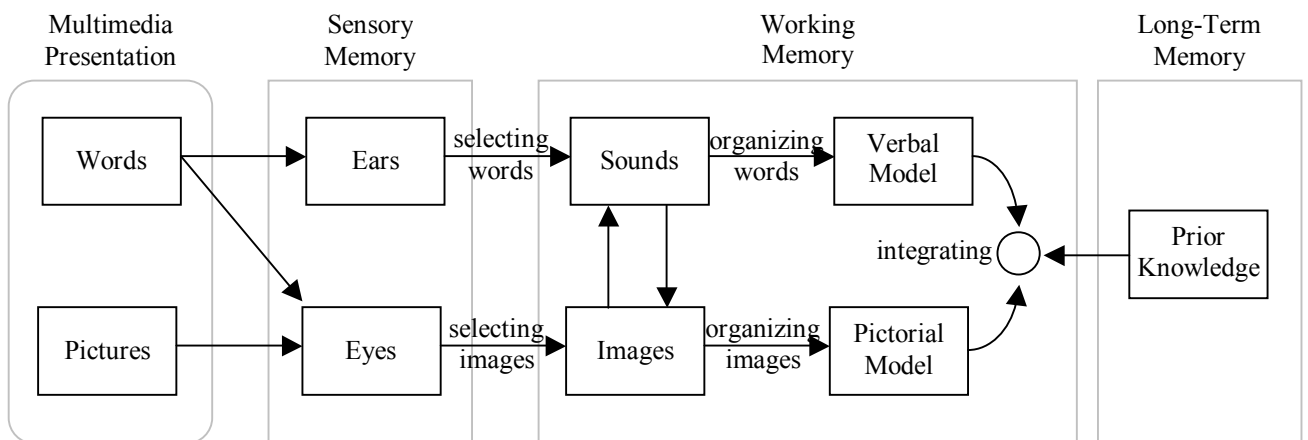


Figure 2. Schematic representation of Mayer’s (2001) cognitive theory of multimedia learning.

The first step in the cognitive theory of multimedia learning (i.e., selecting relevant words) is paying attention to the spoken words presented in the multimedia presentation. These words are passed onto the auditory channel via auditory sensory memory. Due to the capacity limitations of the auditory channel, learners must focus their attentions on the most relevant words presented. The outcome of this step is a mental representation of selected words or phrases in working memory's verbal channel.

The second step (i.e., selecting relevant images) involves paying attention to relevant parts of the image or animation presented in the multimedia presentation. The selected images are initially passed onto the visual channel via visual sensory memory. However, as previously discussed, visual information will automatically be labeled; thus, part of the selected image may be converted to the auditory channel. Due to capacity limitations it is not possible to process all the parts of the image or animation, therefore, selecting only the most relevant images is important. The outcome of this step is a mental representation of selected images in working memory's visual channel.

After the learner has verbal representations of presented spoken words in working memory, he or she must organize the words into a more coherent representation. This transformation takes place in the verbal channel of working memory. Similarly, the process for organizing selected images parallels that for selected words. The learner builds connections among pieces of visual knowledge, which occurs in the visual channel of working memory.

After verbal representations and visual representations have been constructed, the learner must build connections between the two models. This process is called "integrating" by Mayer (1984) and is described as "connecting the organized information

to other familiar knowledge structures already in memory” (p. 33). This process parallels Paivio’s (1990) referential processing in which connections are made between representations in the verbal and visual processing systems. This process takes place in working memory, and again, is constrained by its limited capacity.

The three assumptions and five processes associated with the cognitive theory of multimedia learning are based on working memory, dual-coding theory, and cognitive load theory. They serve as a framework for much of Mayer’s work on multimedia learning. Research studies conducted by Mayer and his colleagues addressing multimedia learning have resulted in several principles of multimedia design. In the following section, these cognitive principles of multimedia are delineated.

Principles of Multimedia Design

Words and pictures offer two different ways of representing information in two independent channels (i.e., verbal and nonverbal). The use of printed and spoken words is most commonly used during instruction (Mayer & Moreno, 2002). However, research suggests that images can have important effects on learning (Levie & Lentz, 1982; Mayer, 1989; Rieber, 1990).

Early studies conducted on the effectiveness of multimedia presentations were based on the use of text and pictures versus the use of text alone (Mayer, 2001). It was predicted that students receiving the presentation with both text and pictures would perform better than those who received text alone. This prediction was based on the premise that humans possess two separate channels for representing verbal and nonverbal information, increasing the likelihood that learners would make referential connections between the two forms of information.

Mayer and his colleagues extended the research on the effect of illustrations in text through a series of experiments (Mayer & Anderson, 1991, 1992; Mayer & Gallini, 1990). Three experiments involved comparisons between students who received text and illustrations versus text alone for explanations how car brakes work, how bicycle tire pumps work, or how electrical generators work. The results of these studies suggest that effective understanding of scientific explanations requires a mapping between words and pictures. Ultimately, the combination of textual and pictorial explanations was more effective in promoting understanding than was giving separate textual and pictorial explanations.

Further studies examined some of the conditions necessary for the effective use of animations in computer-based instruction. A dual-coding hypothesis was tested comparing animation and narration versus animation alone. Mayer and Anderson (1991) first examined these conditions using explanations for how a bicycle tire pump works. The study assessed the effects of viewing an animation of a tire pump and a verbal explanation given before, during, or after the animation on tests of retention, matching, and transfer. The simultaneous presentation of the narration with the animation resulted in significantly better problem-solving transfer performance than the successive presentation group. In a follow-up experiment students either received animation with narration, animation only, narration only, or no training. Again, the results indicated that the students receiving the multimedia presentation (i.e., animation with narration) performed better on tests of problem-solving transfer than students in the other three groups.

Mayer and Anderson (1992) extended their previous work in a second set of experiments. Students studied an animation depicting the operation of a bicycle pump or a car braking system. The animation was presented with either a concurrent narration of the procedural steps, a successive narration of the steps (four different methods), animation only, narration only, or no instruction. Students receiving the concurrent animation and narration performed better on tests of problem-solving transfer than students in the other three groups.

Results of these studies provide additional support for the effectiveness of multimedia. Previous research on text illustrations was extended to include the use of a new type of visual information: animation. By adding illustrations to text or animation to narration, students were able to better understand the scientific explanations. This result is referred to as the *multimedia principle*, which states that “presenting an explanation with words and pictures results in better learning than does presenting words alone” (Mayer, 2001, p. 78).

The research discussed thus far indicates that multimedia works. That is, individuals learn, retain, and transfer information better when the instructional environment involved words and pictures rather than words or pictures alone. The findings are consistent with dual-coding theory (Clark & Paivio, 1991; Paivio, 1990), which emphasizes the verbal and nonverbal representation systems in working memory. In addition, the research was based on Mayer’s (2001) cognitive theory of multimedia learning, which is based on assumptions regarding the information processing system and its limitations along with the concept of active processing.

Knowing that multimedia works is not enough to guarantee its effectiveness. It is necessary to investigate the conditions which are likely to result in multimedia learning. The following sections highlight principles of multimedia design derived from empirical research aimed at understanding the effects of multimedia on learning under a variety of conditions.

Contiguity Principle

The contiguity principle suggests that the effectiveness of multimedia instruction increases when words and pictures are presented contiguously (i.e., rather than isolated from one another) in time and space (Mayer & Anderson, 1992). An assumption of the cognitive theory of multimedia learning is that meaningful learning occurs when learners are able to make connections between corresponding verbal and visual representations in working memory. Thus, the contiguity principle suggests that learners are more likely to make these connections if the corresponding representations are in working memory at the same time.

In a review of ten studies concerning whether multimedia instruction is effective, Mayer (1997) concluded that there was consistent evidence for a *spatial-contiguity effect*, which indicates that learning increases when printed text and pictures are physically integrated or close to each other rather than physically separated (Moreno & Mayer, 1999). This effect is based on the idea that learners are more likely to make appropriate connections between corresponding words and pictures that are near each other in location rather than being separated.

Mayer and Gallini (1990) examined the contiguity effect in a study that looked at discrete text and unlabeled diagrams compared to text with diagrams and appropriately

placed labels. Students who read passages containing the labeled diagrams performed better on tests of problem-solving transfer. Ultimately, the process of appropriately placing labels on a diagram was analogous to physically integrating the two sources of information, which is indicative of spatial contiguity.

A temporal-contiguity effect refers to “learning enhancement when visual and spoken materials are temporally synchronized, that is, presented simultaneously rather than successively” (Moreno & Mayer, 1999, p. 358). This effect is based on the idea that learners are more likely to make appropriate connections between corresponding verbal and visual information if they are presented at the same time. The rationale for the temporal-contiguity effect stems from the limited capacity assumption of multimedia learning, indicating that learners do not have the working memory capacity to hold a narration in working memory until the corresponding animation is presented (Mayer, 1999).

Mayer and Anderson (1991) found evidence for the temporal-contiguity effect in a study where college students low in mechanical knowledge viewed an animation depicting the operation of a bicycle tire pump. In addition to the animation, students were presented a verbal description given either before or during the animation. The researchers found that students who viewed the animation with concurrent (i.e., simultaneous) narration performed better on transfer tests than those who viewed the animation after the narration.

Further support for the temporal-contiguity effect was demonstrated by Mayer and Anderson (1992) in a set of experiments. The purpose of the first experiment was to compare the problem-solving and retention performance of students who received

simultaneous versus successive presentation of animations and narrations of how a bicycle tire pump works. This study differed from their previous work (Mayer & Anderson, 1991) in that control groups were tested and four different methods of successive presentation were used. The purpose of the second experiment was to extend the results of the first by using a different topic, namely, how a car braking system works. The results of both experiments indicated that students receiving concurrent presentation of animation and narration outperformed students in the successive presentation and control groups, thus extending support for the temporal-contiguity effect.

Mayer and Sims (1994) investigated the temporal-contiguity effect by comparing concurrent and successive presentation of animations and narrations of pumping systems and the human respiratory system. The study on pumps was similar to previous studies (Mayer & Anderson, 1991, 1992). The study involving the functioning of the respiratory system used the same procedure but involved a 45-second animation and 100-word narration describing what happens when air is inhaled and exhaled. The results of this set of experiments extended the support for temporal contiguity in that students receiving concurrent animation and narration performed better on transfer tests than students who received the successive presentation.

The contiguity principle has also been described under the name of split-attention effect in cognitive load literature (Chandler & Sweller, 1992; Kalyuga et al., 1999; Kalyuga, Chandler, & Sweller, 2000; Tarmizi & Sweller, 1988). The findings on split-attention stemmed from research conducted on worked examples. Sweller and his colleagues described the split-attention effect as the impairment in learning that results

from the need to mentally integrate disparate sources of information before the material can be understood (Chandler & Sweller, 1991, 1992; Sweller & Chandler, 1994).

Mousavi et al. (1995) determined that students learned better when an auditory narration of a geometry problem presented concurrently with corresponding diagrams than when printed text was presented with the diagrams. A series of studies by Mayer and Moreno (1998) aimed to extend these findings by examining how students integrate animation with concurrent text that is presented auditorily or visually.

Mayer and Moreno's (1998) studies extended Mousavi et al.'s (1995) pioneering research on split-attention in three ways: (a) by examining a split-attention effect in a computer-based multimedia environment rather than a paper-based environment, (b) by using multiple dependent measures, including matching and transfer, and (c) by using cause-and-effect explanations as the target material. Students viewed an animation depicting the process of lightning formation or the operation of a brake system. The students received either concurrent narration or concurrent on-screen text. The results of the studies, as measured by retention, matching, and transfer, indicated a split-attention effect. That is, students could more effectively integrate the nonverbal information (i.e., animation) when it was accompanied by verbal information in an auditory rather than visual modality, which resulted in increased learning.

The results of these studies indicated that students learned better when animation was accompanied by verbal information presented in an auditory rather than visual modality. In addition, the results clarified the conditions producing the contiguity effect by showing that "the advantage of presenting words and corresponding pictures at the same time depends on the modality of the words" (Mayer & Moreno, 1998, p. 318).

Furthermore, the results lend additional support to the dual-channel processing theory of working memory. If learners can hold words in auditory working memory and pictures in visual working memory at the same time, they are better able to build connections between them. Ultimately, the contiguity principle posits that when designing multimedia presentations, corresponding textual and graphical material should be integrated spatially and temporally (i.e., in space and time).

The foregoing section discussed ways to alleviate split-attention effects by integrating verbal and visual materials in time and space, which, in turn decreases the burden imposed on working memory. The following section suggests alternative ways of dealing with these effects by essentially increasing the capacity of working memory.

Modality Principle

The modality principle stems from the limited capacity assumption of the cognitive theory of multimedia learning (Mayer, 2001). Accordingly, it indicates that words should be presented as auditory narration rather than on-screen text when presenting an explanation using multimedia.

Early research on short-term verbal memory provides evidence for a modality effect, referring to the finding that auditory presentation almost always resulted in higher recall than did visual presentation in short-term memory tasks (Penney, 1989). Penney (1989) reviewed the literature on the effects of presentation modality on short-term retention of verbal material and suggested that the effective capacity of working memory can be increased by using both the verbal and visual channels. In another notable study, Frick (1984) found that recall for lists of items is superior when they are presented in

auditory and visual modalities rather than in one modality alone (as cited in Penney, 1989).

Similar findings are evident in research on multimedia learning. Cognitive load theorists pointed to this principle as an alternative way of dealing with split attention. Split-attention effects adversely affect learning because the process of mentally integrating disparate sources of information overloads working memory. However, if the verbal information is presented in auditory (i.e., narration) rather than visual (i.e., written) form, the integration of the sources of information may not overload working memory. By utilizing both channels of working memory the overall capacity of working memory has essentially been increased. Ultimately, “instructional formats in which separate sources of information (otherwise requiring integration) are presented in alternate, auditory or visual, forms might be more efficient than equivalent single-modality formats” (Kalyuga et al., 1999, p. 353).

Mousavi et al. (1995) found evidence for a modality effect in a series of experiments using worked-out geometry examples. The researchers found that a visually presented geometry diagram, coupled with narrated statements, enhanced learning compared to a conventional visual-only format. Tindall-Ford et al. (1997) also investigated the modality effect using basic electrical engineering instructions. The results showed that a narrated text and visual diagram format was superior to a visual-only format.

Mayer and Moreno’s (1998) studies produced the first demonstration of a modality effect within the context of multimedia learning with animations (Moreno & Mayer, 1999). Students were presented with an animation depicting the process of

lightning formation or the operation of a car's brake system. In addition, one group of students was presented a simultaneous narration while the other group received concurrent on-screen text. Students receiving the simultaneous animation and narration performed better on tests of retention, matching, and transfer than students who received animation and on-screen text.

Moreno and Mayer (1999) extended these results in a set of experiments aimed at distinguishing between the effects of contiguity and modality in learning. Students viewed an animation depicting the process of lightning formation. Students in the first experiment either viewed the animation with integrated on-screen text, separated on-screen text, or concurrent narration. On tests of retention, matching, and transfer the students receiving the animation with concurrent narration outperformed both groups receiving animation with on-screen text.

The findings from the first experiment (Moreno & Mayer, 1999) could be interpreted two ways. First, the results may suggest that utilizing both the auditory and visual channels of working memory increases overall memory capacity. However, the group receiving animation and on-screen text were required to attend to two sources of visual information at the same time while this was not required of the narration group. To distinguish between temporal-contiguity and modality effects, Moreno and Mayer (1999) introduced sequential presentations.

The second experiment was designed to examine the modality effect by presenting an animation depicting the process of lightning formation with either simultaneous or sequential presentation of on-screen text or narration. These conditions forced the students to hold the verbal material in working memory either before or after

viewing the animation (Moreno & Mayer, 1999). The researchers predicted that this would eliminate differences in processing that might be due to the competition for visual working memory resources. The researchers also predicted that the advantage of the narrated description should remain when the presentations were sequential. Consequently, both predictions were supported with modality effects demonstrated on tests of retention, matching, and transfer.

Research on the modality effect yields consistent evidence to suggest that in many situations mixed modality presentations are superior to most integrated text and visual presentations (Kalyuga et al., 1999; Mayer & Moreno, 1998; Moreno & Mayer, 1999; Mousavi et al., 1995; Tindall-Ford et al., 1997). An explanation for the increase in learning resulting from the modality principle can be derived from Paivio's (1990) dual-coding theory suggesting that "when learners can concurrently hold words in auditory working memory and pictures in visual working memory, they are better able to devote attentional resources to building connections between them" (Moreno & Mayer, 1999, p. 366). By serving to increase the capacity of working memory, this principle acts as a guiding principle for multimedia designers (Mayer, 2001).

Redundancy Principle

Many multimedia presentations include the presentation of visual materials (e.g., pictures or animations) with simultaneous on-screen text and narration. The rationale for presenting this combination of sources is that it provides the learner with the opportunity to choose the mode of presentation that best suits his or her learning preference (Mayer, 2001; Moreno & Mayer, 2002). Thus, if the same information is presented in multiple modes, more opportunities are available for the learners to use their preferred mode.

However, results from research on the modality principle indicate that words and pictures that are both presented visually increase cognitive load due to the competition for resources in visual working memory (Moreno & Mayer, 1999; Mousavi et al., 1995; Tindall-Ford et al., 1997). Consequently, the *redundancy principle* suggests that removing redundant on-screen text results in better performance than when redundant material is included (Mayer, 2001).

Kalyuga, Chandler, and Sweller (1998; 1999) used the term “redundancy effect” to refer to any multimedia situation in which eliminating redundant material results in better performance than when the redundant material is included (Kalyuga et al., 1998). Kalyuga et al. (1999) saw evidence of a redundancy effect in an experiment aimed at using dual modalities to ameliorate split-attention effects. Students were presented three computer-based instructional formats based on soldering materials: diagram and visual text, diagram and audio text, and diagram and visual-plus-audio text. The diagram and visual text format contained the animation with on-screen text while the diagram and audio text format contained the animation with narration only. The diagram and visual-plus-audio text format contained sequentially introduced animated components of the diagram with written explanations of the elements. The same explanations were simultaneously narrated to correspond with the animation. The results of this experiment confirmed the advantages of dual-modality presentation but they also demonstrated a disadvantage of the duplicate information. Ultimately, eliminating the redundant information proved to be beneficial (Kalyuga et al., 1999).

Mayer, Heiser, and Lonn (2001) used the term redundancy effect in a more restricted sense to refer to “multimedia learning situations in which presenting words as

text and speech is worse than presenting words solely as speech” (p. 187). The researchers examined whether the redundancy effect would occur in a multimedia environment involving animation, on-screen text, and narration. College students viewed an animation and listened to concurrent narration explaining the formation of lightning. The redundancy effect was demonstrated when students who were presented on-screen text that summarized or duplicated the narration performed worse on tests of retention and transfer than students who received only the concurrent narration.

In summary, the redundancy effect generally occurs under conditions in which different sources of information are intelligible in isolation and when both sources provide similar information but in a different form (Kalyuga et al., 2000). Consequently, attending to redundant information requires cognitive resources. That is, if the redundant information is integrated with to-be-remembered information there is no choice but to process it. Thus, attending to redundant material imposes an increased cognitive load, which can be ameliorated by removing the redundant information.

Coherence Principle

Many suggestions regarding the design of multimedia instruction involve the addition of pictures, text, sound, or some other element to make it more interesting. Mayer (2001) called these interesting, but irrelevant, elements *seductive details* and concluded that these details may actually direct attention away from relevant material. From the cognitive theory of multimedia learning, Mayer (2001) derived the *coherence principle*, which is based on the following premises:

- Student learning is hurt when interesting but irrelevant words and pictures are added to a multimedia presentation.

- Student learning is hurt when interesting but irrelevant sounds and music are added to a multimedia presentation.
- Student learning is improved when unneeded words are removed from a multimedia presentation.

The coherence principle is based on the theory that additional text or pictures overload the visual processing system and additional sounds or music overload the auditory processing system, which result in an extraneous cognitive load on working memory.

Mayer et al. (2001) investigated the effects of adding seductive details to a multimedia presentation where college students viewed an animation and listened to concurrent narration explaining the formation of lightning. The first experiment included a group of students who received six additional sentences, interspersed in the narration, which contained seductive details in the form of entertaining but conceptually irrelevant information and another group that received both redundant text and seductive details. The third and fourth experiments in the study included video clip adjuncts that were intended to increase learning by making the presentation more interesting. The clips depicted lightning storms but lacked conceptual relevance to explaining the lightning process. The clips were either presented simultaneously or sequentially. Consequently, lower transfer performance was observed when irrelevant details were added to the narration and when irrelevant video clips were inserted within or before the presentation.

A study conducted by Moreno and Mayer (2000) examined the effects of adding seductive details in the form of auditory adjuncts to a multimedia presentation. The focus of the study was on the limited capacity of the auditory channel and it was hypothesized that the addition of adjunct sounds or music would adversely affect learning. Students

were asked to view an animation depicting the process of lightning formation coupled with one of the following conditions: concurrent narration, concurrent narration plus environmental sounds, concurrent narration plus music, or concurrent narration plus environmental sounds and music. The students scored significantly lower on transfer tests when music was presented than when no music was presented; however, there was no significant difference between students who heard environmental sounds and those who did not receive this form of seductive detail. Consequently, the combination of music and environmental sounds was detrimental to transfer performance.

In summary, the addition of adding the newest “bells and whistles” to multimedia presentations to make them more interesting has a negative effect on student learning. As a result of the irrelevant information, fewer cognitive resources are available for building necessary connections between verbal and visual representations. Ultimately, learning increases when extraneous material is excluded rather than included in multimedia presentations (Mayer, 1999, 2001; Mayer et al., 2001; Moreno & Mayer, 2000)

Individual Differences Principle

What is the role of individual differences in the effectiveness of multimedia instruction? Mayer (1999) suggests that multimedia effects, contiguity effects, and split-attention effects depend on the individual differences in the learner. The resulting principle states that there are “stronger design effects on transfer when learners have low rather than high prior knowledge and high rather than low spatial ability” (Mayer, 1999, p. 621).

According to the cognitive theory of multimedia learning high prior knowledge learners are more able than low prior knowledge learners to generate their own mental

images as they listen to narration or read text, so having a contiguous visual presentation is not needed. Additionally, high knowledge learners are more likely to have verbal and visual representations in working memory at the same time.

In a series of studies consisting of scientific explanations, Mayer and Gallini (1990) tested the performance of students with low or high prior knowledge about the specific topic. Prior knowledge was measured by a self-report questionnaire in which students rated their knowledge of the subject matter on a five-point scale. Overall, the effect on transfer tests of adding illustrations to text averaged 5% for the high prior knowledge learners and 60% for the low prior knowledge learners, thus confirming the prior knowledge prediction of the individual differences principle.

Another prediction regarding this principle is that students with high spatial ability are more able to hold visual images in visual working memory than students with low spatial ability (Mayer, 1997, 1999). Mayer and Sims (1994) conducted a study in which students with high or low spatial ability viewed animations with concurrent or successive narration explaining how pumps work or how the human respiratory system works. Spatial ability was assessed using paper-and-pencil tests of paper folding and mental rotation. The gain in transfer for concurrent presentation of narration and animation averaged 2% for low spatial ability learners and 68% for high spatial ability learners. Ultimately, low spatial ability learners are less likely to have the cognitive resources available to build necessary connections between words and pictures.

The *individual differences principle* takes into account two characteristics of the learner that will influence multimedia learning. Each learner brings different attributes and experiences to any learning situation. However, by taking the individual differences

of the learner into consideration, designers come one step closer to forming instruction that can increase the learner's chance for success.

Segmentation Principle

According to Mayer and Chandler (2001), conventional computer-based applications tend to utilize animation that presents information in a continuous manner and rarely allows the learner to control the pace of the presentation. However, they argue that the use of simple user interaction (i.e., learner control over the pace of the presentation) may have beneficial affects on both cognitive processing during learning and learning outcomes. Specifically, the researchers suggested that simple user interaction would reduce the amount of cognitive load on working memory, thereby allowing the student to build a coherent mental model (Mayer & Chandler, 2001).

Mayer and Chandler (2001) conducted a study conducted to test the effects of simple user interaction on participants' levels of recall and transfer. Participants received a 140-second narrated animation explaining lightning formation either as a system-paced continuous presentation or as a learner-controlled segmented presentation. The system-paced group received a continuous presentation without any breaks, while the learner-controlled group received the presentation as 16 short, user-controlled segments. The results of the study indicated that participants in the segmented presentation group performed significantly better on subsequent tests of transfer than participants in the continuous presentation group; however, there was no significant difference between the groups on the recall test (Mayer & Chandler, 2001). The resulting principle is referred to as the *segmentation principle* and states that transfer is better when a multimedia

presentation (i.e., narrated animation) is presented in learner-controlled segments rather than as a continuous unit.

The results of Mayer and Chandler's (2001) study and the resulting segmentation principle can be explained based on Sweller's (Chandler & Sweller, 1991) cognitive load theory and Mayer's (2001) cognitive theory of multimedia learning. In system-paced presentations individuals may lack sufficient time and cognitive resources to make connections between verbal and nonverbal representations before being presented new information, resulting in cognitive overload. However, when an individual has control over the progression of the presentation, the individual may pace the presentation so that time and cognitive resources are allotted for making connections between verbal and nonverbal (i.e., visual) representations before moving onto to new information (Doolittle et al., 2004). Mayer and Moreno (2003), in discussing the segmentation principle in light of the cognitive theory of multimedia, attributed the findings to the fact that participants in the segmented presentation group had more study time, thus allowing them to organize and integrate the words and images selected from one segment before proceeding to the next.

Summary

The principles discussed in this section of the literature review have been the focus of over a decade's worth of research for Richard Mayer and his colleagues. Based on his cognitive theory of multimedia learning Mayer (2001) posits that designing multimedia according to these principles can result in meaningful learning. By focusing on how people learn, research on multimedia can provide empirical and practical implications for the design of multimedia applications in instructional settings. Table 1

summarizes the principles derived from research on multimedia effects and provides practical applications for their use.

Table 1

Multimedia Design Principles and Applications

Design Principle	Practical Application
Multimedia Principle	Learning is greater when information is presented as words and pictures, rather than words or pictures alone.
Spatial-Contiguity Principle	When presenting corresponding text and images, the text should be in close proximity to or embedded within the images.
Temporal-Contiguity Principle	Corresponding text and images or corresponding narration and animation should be presented simultaneously.
Modality Principle	Auditory or spoken words should be used to accompany images or animation.
Redundancy Principle	When coupled with corresponding images or animation, text should be in either written form or auditory form, but not both.
Coherence Principle	Avoid adding irrelevant information to multimedia presentations on the basis of increasing interest or making more enjoyable.
Individual Differences Principle	The foregoing applications are most effective for learners who have low prior knowledge of the topic of interest and learners who are high in spatial ability.
Segmentation Principle	Learning is greater when a narrated animation is presented in short, learner-paced segments rather than as a longer continuous presentation.

Computer-based multimedia environments offer a venue where verbal and nonverbal information can be easily combined. By designing instruction according to theories of how people learn, a powerful communication device (i.e., the computer) can be used to deliver multimedia presentations. Consequently, when designed effectively, multimedia can improve learning. However, much of the research thus far has focused on using multimedia to teach scientific, cause-and-effect explanations with intellectual skills as the desired learning outcome. Mayer (1999) cites this as a limitation to the results of his studies indicating that additional work is needed to examine the effects of multimedia on learning other kinds of material.

Computer-based, multimedia instruction has seldom focused on strategy development as the desired learning outcome (Dehn, 1997; Hartley, 2001). A strategy is a guide that serves to support learners during less-structured tasks. How to teach strategies has been the subject of interest for researchers in the areas of reading, math, and writing for decades. The next section of this review explores the importance of strategies in the learning process as they represent the learning outcome that was the focus of the present study. Additionally, research regarding effective ways to provide strategy instruction in traditional learning environments is reviewed.

Strategy Development

Strategies

In general, strategies are tools or methods available to the learner that can be used to accomplish some goal. More specifically, they can be defined as internal control processes by which learners select and modify their ways of attending, learning, remembering, and thinking (Gagne, Briggs, & Wager, 1988). Another definition offered

by Schneider and Weinert (1990), suggests that strategies are “goal-directed processes which may involve automatic, non-strategic operations, but which are potentially available to consciousness” (p. 289). This description implies that when strategies are first being developed, the learner may have to employ conscious effort to implement the strategy but with time and practice the learner can execute the strategy with little attention to its processes; that is, strategies can become automatized.

Strategies represent one of the five major categories of learning outcomes (Driscoll, 2000). Gagne (1985) contends that strategies represent the executive control functions of information processing, which has also been termed metacognitive knowledge. According to Rosenshine, Meister, and Chapman (1996) students often employ strategies when they are faced with less-structured tasks, which are tasks that cannot be broken down into a fixed sequence of steps that consistently lead to the same results.

According to Pressley, Borkowski, and Schneider (1987) strategies are of little value if the learner does not have them, does not implement them appropriately during the course of a learning endeavor, or cannot use them in the face of distraction. In addition, the researchers suggest that there are five components of good strategy use, which include the following:

1. Good strategy users have many strategies available to them for obtaining goals.
2. Good strategy users know how, when, and where to apply each of the strategies.

That is, good strategy users have effective procedural and conditional knowledge related to strategy usage.

3. Good strategy users possess the general understanding that performance is tied to effort and that strategic actions are most likely to be successful if distractions can be ignored.
4. Good strategy users have non-strategic knowledge about the world. That is, they have a broad knowledge base which ultimately improves the efficiency of strategy execution.
5. Good strategy users have automatized the use of strategies.

According to Pressley et al.'s (1987) Good Strategy User model, there are three broad categories of strategies that are available to learners. *Goal-specific strategies* are used for different types of comprehension, problem-solving, and memory tasks.

Monitoring strategies are responsible for the control and regulation of goal-specific strategies. Finally, *higher-order sequencing strategies* are suitable for achieving performance goals. Without specific strategy knowledge, individuals would not know when to apply each of these strategies. Such knowledge can be acquired from exposure to a variety of strategies or through instruction on when, why, and how to apply certain strategies and how to monitor their effective use.

The strategies described by Pressley et al. (1987) can also be classified as cognitive or metacognitive. Flavell (1979) suggests that cognitive strategies are employed to make cognitive progress while metacognitive strategies are used to monitor that progress. Hofer, Yu, and Pintrich (1998) identified rehearsal, elaboration, and organization strategies as important cognitive strategies related to academic performance in the classroom. In addition, the researchers emphasize that elaboration and organization strategies result in deeper understanding than mere rehearsal strategies.

Besides cognitive strategies, Hofer et al. (1998) contend that metacognitive strategies, such as those used to monitor, control, and regulate one's thought processes, have an important influence on achievement. Specifically, they specify planning, monitoring, and regulating strategies as metacognitive strategies commonly cited in models of metacognition and self-regulation. Accordingly, the goal-specific strategies described by Pressley et al. (1987) could be classified as cognitive strategies while the monitoring and higher-order sequencing strategies could be classified as metacognitive strategies.

Strategies, cognitive and metacognitive, serve as guides for students. They represent skills that allow students to select and guide the internal processes involved in learning and thinking (Gagne et al., 1988). However, without the necessary strategies or information regarding when, why, and how to use such strategies, learners may not reach the desired end results for a variety of learning tasks. Consequently, Hartley (2001) suggests that the effective application and effectiveness of a number of strategies depends on the learners' level of metacognition.

Metacognition

Metacognition is a multidimensional construct grounded in psychological and educational theory. Literally, metacognition means "cognition about cognition" or "thinking about thinking" and consists of two distinct dimensions: knowledge of cognition and regulation of cognition (Brown, 1987; Flavell, 1979). This distinction between *knowledge of cognition* and *regulation of cognition* remains the focus of research interested in investigating how students can develop metacognitive skills and subsequently use those skills during the course of a cognitive endeavor.

Knowledge of Cognition

Much of the early research on metacognition focused on the *knowledge of cognition* dimension, which refers to what learners know about their own cognition, about the cognition of others, and about cognition in general. This type of knowledge has been further characterized as the *variables* comprising the store of metacognitive knowledge and the *type of knowledge* contained in that store. Ultimately, this dimension encompasses a person's beliefs and knowledge regarding *person variables*, *task variables*, and *strategy variables*.

Knowledge of *person variables* refers to the category that encompasses everything a learner comes to believe about the nature of himself or herself and other people as cognitive processors. Knowledge of *task variables* is acquired as children learn how the nature of different learning materials affects and constrains how one should deal with them. Eventually students begin to understand the qualities about different types of material as well as what kind of processing is required to understand them. Finally, knowledge of *strategy variables* incorporates the means available to succeed at reaching various goals. Students learn a wide variety of strategies that allow them to achieve cognitive goals as well as monitor their progress while working towards such goals.

Knowledge of cognition can be further subdivided into three kinds of metacognitive knowledge: declarative, procedural, and conditional (Brown, 1987; Schraw & Moshman, 1995). Generally speaking, these components of metacognitive knowledge refer to the “what, how, why, when, and where” aspects of cognition.

Declarative knowledge includes the knowledge one has “about” oneself and “what” factors will influence his or her performance. In addition to personal factors,

learners acquire “fact-based” knowledge about the nature of various tasks as well as what strategies can be used to reach cognitive goals. For example, learners “know that” to solve a math problem they must use certain mathematical operations or to learn about a period in history they must be able to locate events within an immediate and broader context.

Procedural knowledge refers to knowledge about how to perform certain skills or carry out certain activities. Research indicates that learners who possess a high degree of procedural knowledge use skills more automatically and are more likely to sequence strategies effectively (Pressley et al., 1987). Much of this type of knowledge is represented as strategies, both cognitive and metacognitive. For example, most learners have developed strategies for how to go about reading a text for meaning. They may employ cognitive strategies such as underlining or outlining to ensure that they understand the text. This may be followed by an attempt to go back and reread the underlined segments of the text or adding details to the outline so as to ensure comprehension. The latter strategies serve a metacognitive purpose. Ultimately, the knowledge of “how” to employ each of these strategies is representative of procedural knowledge.

Conditional knowledge refers knowing when and why various cognitive strategies and actions should be applied (Garner, 1990). Essentially, this type of knowledge indicates when and why declarative and procedural knowledge should be used. In a study comparing college students, researchers found a positive relationship between conditional knowledge about the effectiveness of strategies and strategy use (Justice & Weaver-McDougall, 1989). Simply knowing that a strategy exists and how to use it does

not guarantee its utility and effectiveness. Instead, learners need to know when and why to employ a strategy to ensure its utility and maintenance.

In summary, the knowledge of cognition dimension is characterized by the learner's knowledge regarding a number of variables, which can be characterized as declarative, procedural, or conditional. Essentially, throughout the course of development individuals learn a great deal about themselves as learners, about others, and about cognition in general. All of these variables and different types of knowledge act and interact to provide the learner with a metacognitive knowledge base that can inform the student during some cognitive endeavor. However, while knowledge of cognition is a necessary condition for metacognitive skill, it is not sufficient. Only when students are able to reflect on that knowledge can they use it to monitor and regulate their cognitive progress. Thus, the regulatory dimension of metacognition is discussed in the following section.

Regulation of Cognition

In general, the *regulation of cognition* dimension of metacognition is concerned with a variety of decisions and strategies that individuals make to regulate their learning. This dimension also represents the link between metacognition and self-regulated learning. Metacognitively, "self-regulated learners are persons who plan, organize, self-instruct, self-monitor, and self-evaluate at various stages during the learning process" (Zimmerman, 1986, p. 308). Regulation is a more observable dimension of metacognition, usually referring to metacognitive strategies. Most models of metacognitive control or self-regulation include the following types of strategies:

planning, monitoring, and evaluation (Brown, 1987; Corno, 1986; Schraw & Moshman, 1995; Zimmerman, 1986; Zimmerman & Martinez-Pons, 1986).

Planning involves the selection of appropriate strategies and the allocation of resources that affect task performance. This aspect of regulation is goal related, requires knowledge about the task as well as oneself, and involves the initial selection of appropriate strategies (Schmitt & Newby, 1986). Planning activities that have been the focus of investigations include setting goals for studying, skimming a text before reading, generating questions before reading, and doing a task analysis of a given problem (Hofer et al., 1998). Consequently, learners who report using these types of planning strategies seem to perform better on a variety of academic tasks than students who do not incorporate these strategies into their learning (Brown et al., 1983; Zimmerman, 1989). In addition, it has been found that more experienced, skilled learners possess more metacognitive knowledge and use that knowledge to regulate their learning before they engage in a task (Schraw & Moshman, 1995). That is, expert learners tend to use their existing knowledge to plan their cognitive activities.

Monitoring involves ongoing executive control of cognitive processes and is a crucial component of metacognition (Hofer et al., 1998; Schmitt & Newby, 1986). Researchers have found that by involving students in self-monitoring, they can improve students' academic achievement, time on task, classroom behavior, and problem-solving ability.

The monitoring process occurs while the learner is engaged in a task and typically involves an awareness of what one is doing, an understanding of why, when, and where it fits into the learning sequence, and an anticipation and planning for what is

coming next (Ertmer & Newby, 1996). Researchers suggest that regularity and proximity are two important characteristics of effective self monitoring (Bandura, 1986; Shapiro, 1984) (as cited in Lan, 1998). Regularity refers to learners continuously, rather than intermittently, monitoring their learning while proximity refers to the self-monitoring of learning behavior close to the time of its occurrence, rather than a long time afterward.

Monitoring strategies alert the learner to breakdowns in attention and comprehension that can be repaired through the use of regulatory strategies. Examples of monitoring strategies include tracking one's attention while reading or listening to a lecture, self-testing through the use of questions about the material to check for understanding, and monitoring comprehension of the given material (Hofer et al., 1998). Ultimately, monitoring consists of "checking and evaluating to determine whether the task matches preconceived notions about it, whether selected strategies are working, whether task performance is adequate, or whether comprehension is proceeding as it should" (Schmitt & Newby, 1986, p. 30).

Research indicates that monitoring ability develops slowly and is quite poor in children and even adults (Pressley, Levin, & Ghatala, 1984). However, recent studies suggest that monitoring ability can be improved with training and practice (Osman & Hannafin, 1992). For example, Lan (1998) conducted a study with graduate students to determine how self-monitoring affected various aspects of college students' learning. Over the course of four semesters, the researcher implemented a self-monitoring intervention to four different graduate level introductory statistics courses. The results indicated that students who received the self-monitoring intervention outperformed their counterparts in control conditions.

The last regulatory strategy commonly depicted in models of metacognition and self-regulation are *evaluation* strategies, which involve assessing the regulatory processes used and the end product achieved (Ertmer & Newby, 1996). A number of studies indicate that metacognitive knowledge and regulatory skills such as planning are related to evaluation (Baker, 1989; Schraw, 1998; Schraw & Moshman, 1995). Ultimately, evaluation emphasizes the process that brought the learner to the end product and is reflective in nature. That is, evaluation calls for a revision of strategies if the desired goal is not achieved.

By employing reflective thinking skills to evaluate the results of one's cognitive activity, students develop an understanding that effective learning strategies can be increased and ways to transfer these strategies can be understood. The knowledge that is gained through the process of reflection is based on existing knowledge a person has about person, task, and strategy variables. Consequently, researchers and educators are becoming convinced of the importance of evaluation and are considering ways to incorporate this regulatory strategy into instruction (Ertmer & Newby, 1996).

In summary, *regulation of cognition* represents a dimension of metacognition that comprises learning strategies devoted to planning, monitoring, and evaluating one's learning efforts. Consequently, these strategies are also cited as integral subprocesses in theories of self-regulated learning. Each type of strategy has unique features and functions, however, it must be noted that they are not used in isolation from each other or from the knowledge dimension of metacognition. Ultimately, the knowledge individuals have regarding various factors concerning themselves, the learning task, and strategies will influence their ability to monitor and regulate their learning and vice versa.

The knowledge learners have regarding their own thought processes (i.e., knowledge of cognition) and their ability to regulate those thought processes (i.e., regulation of cognition) are important components of learning. Improvements in thinking and problem solving as well as increases in achievement in a variety of domains have been achieved by emphasizing metacognitive processes during instruction (Bransford, Sherwood, Vye, & Rieser, 1986). The following section addresses the use of explicit instruction to train cognitive and metacognitive strategies while emphasizing the role of metacognitive knowledge in effective strategy interventions.

Strategy Interventions

Through an extensive meta-analysis on learning strategy interventions, Hattie, Briggs, and Purdie (1996) suggested that strategy interventions are cognitive, metacognitive, or affective in nature. *Cognitive interventions* focus on developing certain task-related skills. *Metacognitive interventions* focus on the self-management of learning and on the conditional knowledge specific to strategies and their appropriate contexts. *Affective interventions* focus on the non-cognitive aspects of learning such as motivation and attitude.

Hattie and his colleagues (1996) concluded that *metacognitive interventions*, taught in context and orchestrated to suit a particular task, are expected to be the most successful. Results of the meta-analysis (Hattie et al., 1996) also supported the claim that strategies should be taught with an understanding of the conditions under which the strategy works (i.e., conditional knowledge). That is, to promote maintenance and transfer, the student must understand how the strategy works and how to use it as well as when and under what circumstances its use is most appropriate.

Strategy training can also be classified as *blind training*, *informed training*, or *self-controlled training* (Brown et al., 1981). *Blind training* involves presenting declarative and procedural knowledge about what the strategy is and how to use it but fails to explain why and when to use the strategy (i.e., conditional knowledge). For example, a student may learn about a self-questioning strategy, in which he or she is given a description of the strategy and detailed explanations of how to incorporate the strategy without given a reason for using the strategy. On the other hand, *informed training* includes the rationale, significance, and utility of the trained activity or strategy. That is, students are given pertinent information regarding when the strategy should be used and why it is important. Finally, *self-controlled training* involves developing an awareness of one's mental processes as well as the tools through which mental processes can be effectively and independently invoked and monitored (Osman & Hannafin, 1992). Essentially, learners are advised of the strategies and their utility as well as how to use, monitor, and evaluate the use of those strategies.

Brown and Palincsar (1982) conducted a study comparing blind, informed, and self-controlled training approaches. The researchers found that students who received *blind training* improved performance but failed to use the skills on their own or to generalize them to similar situations. Incidentally, students who received *informed training* showed increased performance but also demonstrated maintenance of the skill in appropriate situations. Finally, students who received *self-controlled training* exhibited increased learning outcomes in terms of strategy use, strategy effectiveness, and self-regulation.

Dehn (1997) explored the differences between informed and blind strategy training on participants' levels of reading comprehension and metacognitive awareness. The *informed strategy training* provided instruction on the rationale, significance, and utility of using the strategy. The *blind strategy training* was less explicit about the strategies and the rationale for their use. The researcher hypothesized that the strategy instruction would improve metacognitive awareness and achievement. Consequently, the results of the study indicated that the group receiving informed strategy training demonstrated a higher level of reading awareness and strategy knowledge than the group who received blind strategy training (Dehn, 1997).

Gredler (1997) also indicates *informed training* as a necessary condition for successful strategy instruction. Specifically, the researcher indicates that instruction should be explicit in describing situations and task demands where particular strategies may be appropriate. In addition to informed training, he proposes that student assessment should reflect the kinds of metacognitive skills developed throughout the instruction and supports for engaging in metacognitive activities should be provided with the instruction (Gredler, 1997).

The consequences of adding metacognitive knowledge (i.e., conditional knowledge) about specific strategies during instruction is referred to as an *informed training* approach. Compared with bare-bones strategy instruction, interventions that incorporate this approach and include specific information regarding the utility of the strategy lead to more effective strategy deployment and better performance (Pressley et al., 1990). Furthermore, supplementing strategy interventions with metacognitive knowledge regarding the target strategy may increase both strategy maintenance and

strategy generalization (Pressley et al., 1990; Symons, Snyder, Cariglia-Bull, & Pressley, 1989).

Another characteristic of successful strategy instruction commonly noted in the literature is the gradual transfer of control of the strategy from the teacher to the student. This guided, interactive instruction is known as *scaffolded instruction*, with scaffolding referring to the temporary support used to assist the student during initial learning. This type of instruction allows teachers to help students bridge the gap between their current abilities and goals (Rosenshine et al., 1996). Scaffolding commonly takes the form of *process prompts* or *process modeling* by a teacher or expert that allows comparisons between an expert's strategy use and that of the learner (Lin, Hmelo, Kinzer, & Secules, 1999).

Process prompts encourage students to stop, think, and reflect upon their thought processes while engaged in a particular cognitive task. These prompts provide a means of externalizing mental activities by posing questions and guiding students in tracking and understanding their own cognitive activity. Essentially, this design feature helps students organize, monitor, and evaluate their approach to problem-solving while learning. However, Osman and Hannafin (1992) caution designers on the use of external cues for stimulating the monitoring process, arguing that learners "must develop both the ability to monitor their own learning, as well as the attitudes required to invoke strategies on their own" (p. 88).

In contrast to process prompts, *process modeling* focuses on the thought processes that an expert would use in a given situation. The expert's thought processes are then used as a model for students who are approaching a novel task. This type of modeling

allows students to “build an integrated understanding of processes by seeing what is happening while hearing a verbal explanation of why the process is occurring” (Lin et al., 1999, p. 50). In short, one of the major functions of modeling is to provide scaffolding to help students acquire a deeper understanding of their own thought processes by comparing and contrasting themselves to expert-like models. Thus, the premise behind modeling is that learners can gain valuable knowledge from experts sharing and demonstrating their strategic processes.

Ertmer and Newby (1996) discuss the implications that the concept of expert learning and modeling has for instructional practices. The researchers suggest that experts are not distinguished merely by the amount of knowledge or number of skills they possess. Instead, it is their ability to implement appropriate strategies “when they become aware that certain facts or skills are missing from their learning repertoires that are necessary for reaching desired academic goals” (Ertmer & Newby, 1996, p. 1). It is the monitoring and self-regulatory skills that enable experts to know not only what is important, but also how, when, and why to apply appropriate knowledge and strategies. In addition, Ertmer and Newby (1996) emphasize the importance of reflection in linking learners’ metacognitive knowledge and self-regulatory processes. It is through the process of reflection that learners utilize existing knowledge about person, task, and strategy variables during the various stages of regulation.

It has been suggested that expert learners reach a level of performance characterized as smooth, quick, and automatic by spending a considerable amount of time practicing (Ertmer & Newby, 1996). Consequently, novice learners need extensive *practice* using various strategies in realistic contexts if they are to be automatically and

effectively implemented. This notion is supported by Gagne (1984) who points out that strategies are developed similarly to procedural skills, suggesting that practice is essential for strategy development.

Modeling of expert processes offers a valuable method for promoting the learning of strategies. Volet (1991) argues that effective strategy instruction requires that teachers teach metacognitively and that students should be taught the content material and the associated metacognitive skills at the same time. That is, strategy instruction should be taught in context by a teacher modeling the to-be-acquired strategies.

In summary, research on strategy interventions has yielded various results that have important implications for the design of effective strategy instruction. A central theme that has resulted from the research is that it is not enough to teach only the procedural aspects of a strategy. Instead, pertinent knowledge regarding the significance and utility of the strategy must also be incorporated into the training to ensure successful deployment and maintenance of the strategy. Additional guidelines for effective strategy instruction were gleaned from the literature and are described in Table 2.

Table 2

Guidelines for Effective Strategy Instruction

Guideline	Explanation
<i>Strategy instruction should be contextual</i>	<ul style="list-style-type: none"> Strategies should be taught with explicit reference to the particular content with which they eventually will be applied. Students should be taught the content of a discipline and the relevant metacognitive skills needed to handle that content at the same time.
<i>Strategy instruction should be direct and explicit</i>	<ul style="list-style-type: none"> Strategy instruction should emphasize explicit explanation of the mental processes involved in executing the desired strategies. Teachers should provide a complete and explicit explanation to their students regarding what the strategy is, how, when, and where to use it, as well as why it should be learned. Direct explanation should involve the use of feedback, modeling, and teacher-guided student practice.
<i>Strategy instruction should incorporate an informed training approach</i>	<ul style="list-style-type: none"> The situation and task demands where particular strategies may be appropriate must be made explicit. Students need to be provided information regarding the significance of the strategies as well as when and why the strategies should be used.
<i>Strategy instruction should incorporate scaffolding</i>	<ul style="list-style-type: none"> It is suggested that strategies evolve through a process of “guided discovery.” Scaffolding commonly takes the form of process prompts or modeling by a teacher or expert that allows comparisons between an expert’s strategy use and that of the learner.
<i>Strategy instruction should provide opportunities for practice and feedback</i>	<ul style="list-style-type: none"> Instruction should be followed by opportunities for practice. Students should be provided feedback regarding the usefulness of strategies and the success with which they are being acquired.

Summary

A strategy is a guide that serves to support learners during less-structured tasks. How to teach strategies has been the subject of interest for researchers in the areas of reading, math, and writing for decades. Resulting research has indicated that students who were explicitly taught various strategies obtained significantly higher scores than those in control groups (Rosenshine et al., 1996). Moreover, researchers understanding the role of metacognition in strategy development have found that providing learners with specific information regarding when and why to use a specific strategy leads to more effective strategy deployment and better performance (Braten, 1993). Ultimately, research on both strategy interventions and metacognition provides numerous guidelines for how to design instruction if strategy development is the desired learning outcome.

Synthesis

Significant advances in the realm of multimedia have been made over the last several decades. Multimedia instruction that was once developed according to technology availability and capability has been transformed with the current focus addressing how the multimedia environment can be designed to aid human learning. Ultimately, the focus has shifted away from the technology capabilities and toward the information processing system of the learner.

This shift from a “technology-centered” to a “learner-centered” approach has resulted in significant research in the area of multimedia design. Parallels can be drawn between multimedia and the way people learn as explained by working memory models, dual coding theory, and cognitive load theory. Richard Mayer and his colleagues have spent years applying these theories of learning and cognition to the development of

effective multimedia instructional environments (for overview, see Mayer, 2001). This research has resulted in several principles which aid in the design and development of multimedia instruction (see Table 1). However, the results of this research are limited in that the instruction provided in the studies focused solely on scientific cause-and-effect explanations.

Strategies represent a learning outcome with little history of focus in the multimedia environment (Dehn, 1997; Hartley, 2001). While learners can acquire strategies through day-to-day experiences, strategies can also be taught explicitly, which has resulted in greater deployment and maintenance in a variety of domains (Brown et al., 1981; Dehn, 1997; Mayo, 1993; McCombs, 1988; Palincsar, 1986; Pressley, Snyder, Levin, Murray, & Ghatala, 1987) . The findings from such research indicate that when teaching strategies the instruction should take place within a specific context and should address essential metacognitive knowledge regarding the significance and utility of the strategy. Additionally, the instruction should be scaffolded and provide the learners opportunities to practice the trained strategy and receive feedback regarding their strategy use. (Brown et al., 1981; Dehn, 1997; Gredler, 1997; Palincsar, 1986; Pressley et al., 1990).

With strategies playing an important role in the learning process and the use of computer-based multimedia instruction becoming increasingly more commonplace it seems prudent to attempt to answer the following questions: Do the guidelines for strategy instruction deemed effective in traditional learning environments transfer to the multimedia learning environment? Do the multimedia effects discovered in the instruction of scientific explanations have the same effects when the focus of the

instruction is strategy development? Thus, this researcher hopes to build on the multimedia and strategy literature by exploring the effects of explicit multimedia instruction and established multimedia design principles on strategy development.

Significance of the Study

The purpose of this study was to assess the effects of strategy training, modality of presentation (i.e., modality), and redundant verbal information (i.e., redundancy) on the participants' ability to apply and recall a historical inquiry strategy. Research in the area of multimedia instruction has yielded results that indicate that learning is better when verbal information is presented auditorily instead of visually (i.e. modality effect) and when redundant on-screen text is removed from the instructional environment (i.e. redundancy effect) (Mayer & Anderson, 1991, 1992; Mayer et al., 2001; Mayer & Sims, 1994). However, these results are limited in that the studies focused on short, system-paced multimedia presentations designed to teach scientific explanations which utilized animation to depict a cause-and-effect relationship.

The present study aimed to extend these findings by exploring the effects of presentation modality and redundancy of verbal information on a different learning outcome (i.e., strategy development) while utilizing animation for a different purpose and providing a longer, learner-paced presentation. Specifically, the present study differed from the studies on the modality and redundancy effects conducted by Mayer and his colleagues in the following ways: (a) the focus of the multimedia instruction was on the development of a historical inquiry strategy (i.e., cognitive strategy) rather than understanding a scientific cause-and-effect explanation (i.e., intellectual skill), (b) the purpose of the animation was to guide learning by signaling important information rather

than to illustrate a cause-and-effect relationship, and(c) the multimedia instruction was two hours in length and learner-paced rather than short (i.e., less than 3 minutes) and system-paced. A summary of these differences is provided in Table 3 and explained in the subsequent paragraphs.

Table 3

Differences Between Mayer's Studies and Present Study

	Mayer's Studies	Present Study
Learning Outcome of Interest	Intellectual skill	Cognitive strategy
Purpose of Animation	Relational depiction	Signaling
Length of Instruction	< 3 minutes	2 hours
Pace of Instruction	System-paced	Learner-paced

The focus on cognitive strategy development as opposed to intellectual skills as the desired learning outcome led to the differences in animation and length of instruction used in the study. When cognitive strategy development is the desired learning outcome, instruction is designed to change the way in which learners select and guide the internal processes of thinking and learning (e.g., use of strategy to monitor understanding). Additionally, because strategies focus on the internal cognitive processes of the learner, they are less descriptive and explanatory in nature than intellectual skills (Tabbers, Martens, & van Merriënboer, 2004) and not as readily externalized or visualized. Consequently, the animation used in the present study served a signaling or guiding purpose rather than providing a relational depiction.

Research on strategy development indicates that instruction needs to go beyond the “one-shot” training sessions and provide learners with substantial teaching and practice (Borkowski & Muthukrishna, 1992). Therefore, the strategy instruction used in the present study was two hours in length and designed to allow numerous opportunities for review and practice. The length of instruction in this study contrasts sharply with the three minutes of instruction provided in Mayer’s studies on the modality and redundancy effects.

Finally, in addition to providing a longer period of instruction, the present study also incorporated a segmented, learner-paced presentation. Mayer and Chandler (2001) found evidence for the beneficial effects of segmentation; however, the study did not address the effects of modality and redundancy. Incidentally, the studies that focused on determining the effects of modality and redundancy on retention and transfer all utilized a system-paced presentation that did not provide any breaks in the instruction.

Ultimately, this researcher seeks to determine whether the results and conclusions from earlier research on the modality and redundancy effects hold true for instruction that is focused on strategy development, utilizes animation for signaling purposes, is substantial in length, and is learner-paced. It is hoped that the results of this study will extend the literature that suggests that learning is better when verbal information is presented auditorily instead of visually (i.e. modality effect) and when redundant on-screen text is removed from the instructional environment (i.e. redundancy effect).

Research Questions

The study explored the impact that strategy training, modality of presentation, and redundant verbal information had on students' application and recall of a historical inquiry strategy. Specifically, this study sought to answer the following questions:

1. Can strategy instruction be provided effectively in a multimedia environment?
2. What are the effects of multimedia presentation *modality* on students' performance on tests of strategy application and recall?
3. What are the effects of multimedia presentation *redundancy* on students' performance on tests of strategy application and recall?

METHOD

Introduction

The purpose of this study was to assess the effects of strategy training, modality of presentation (i.e., modality), and redundant verbal information (i.e., redundancy) on the participants’ ability to apply and recall a historical inquiry strategy. A multimedia tutorial was used to deliver instruction on the SCIM strategy for historical inquiry, which helps students gain the knowledge and skills necessary to analyze and interpret historical primary sources (Hicks, Doolittle, & Ewing, 2004). This chapter outlines the approach that was used to answer the research questions in this study, detailing the experimental design, participants, materials, and procedures.

Research Design

The study employed a 3 (Animation-Narration [AN], Animation-Text [AT], Animation-Narration-Text [ANT]) x 3 (pre-test, post-test, maintenance test) repeated measures research design (see Figure 3). The effects of training, modality, and redundancy on participant *application* of a historical inquiry strategy were assessed.

	Pre-test	Post-test	Maintenance test
Animation-Narration (AN)			
Animation-Text (AT)			
Animation-Narration-Text (ANT)			

Figure 3. Representation of repeated measures research design.

This study also employed a 3 (AN, AT, ANT) x 1 (post-test) single-factor research design (see Figure 4). The effects of modality and redundancy on participant

recall of an historical inquiry strategy were assessed through the use of this research design.

	Post-test
Animation-Narration (AN)	
Animation-Text (AT)	
Animation-Narration-Text (ANT)	

Figure 4. Representation of single-factor research design.

Participants

A total of 56 participants completed the study. The sample was drawn from a population of students enrolled in undergraduate and graduate level courses in teacher education. As an incentive, the faculty teaching the courses offered study participation as (a) an assignment, (b) in lieu of an assignment, or (c) as extra credit. The participants were pre-service teachers majoring in a variety of different program areas predominantly located in the School of Education at a large land-grant institution in the southeast.

The ages of participants ranged from 19 to 31 ($M=21.48$). Eighty-two percent ($n=46$) of the sample were female and 18% were male ($n=10$). Seventy-seven percent ($n=43$) of the participants were undergraduate students with 20% ($n=11$) seniors, 41% ($n=23$) juniors, 12% ($n=7$) sophomores, and 4% ($n=2$) freshman. The remaining 23% ($n=13$) of the participants were graduate students at the master's level. Seventy-three percent ($n=41$) of the participants indicated that their nationality was White/Caucasian while the remaining 27% were of Black/African American ($n=5$), American Indian/Alaskan Native ($n=1$), Asian ($n=3$), Hispanic/Latino ($n=2$), Multiracial ($n=3$), and Other ($n=1$) descents.

Variables of Interest

*Independent Variable**Presentation Mode Combination*

The independent variable of interest in this study was the combination of presentation modes used to present the strategy instruction. A *presentation mode* refers to the format used to represent the presented instruction (e.g. words, pictures, and animation) and is associated with one or more sensory modalities (Mayer, 1997). A *sensory modality* refers to the information processing channel that a learner uses to process information such as visual versus auditory modality (Mayer, 1997).

The study explored the effects of three different presentation mode combinations. The combinations differed in the sensory modalities, visual or auditory, used to perceive and initially process information. The *visual sensory modality* initially processes information that is perceived through the eyes (e.g., text, animation) while the *auditory sensory modality* initially processes information that is perceived through the ears (e.g., narration, sounds).

The first presentation mode combination consisted of animation and narration (AN). Animation corresponds with the visual sensory modality while the narration corresponds with the auditory sensory modality. The second presentation mode combination consisted of animation and text (AT), which both correspond with the visual sensory modality. The AN and AT combinations were used to test the *modality principle*. Previous research regarding the modality principle indicates that when presenting a multimedia explanation, including auditory narration rather than on-screen text results in

increased levels of retention, matching, and transfer (Kalyuga et al., 1999; Mayer & Moreno, 1998; Moreno & Mayer, 1999; Mousavi et al., 1995; Tindall-Ford et al., 1997).

The third presentation mode combination consisted of animation, narration, and text (ANT). This combination represents two visual sensory modes (i.e., animation, on-screen text) and one auditory sensory mode (i.e., narration). This combination was used to test the *redundancy principle*. Previous research regarding the redundancy principle indicates that removing redundant text (i.e., text that is the same as the narration) from multimedia explanations results in increased levels of retention and transfer (Mayer et al., 2001; Moreno & Mayer, 2002; Mousavi et al., 1995).

Dependent Variables

Strategy Application

The participants were assessed on their ability to apply the SCIM strategy for historical inquiry. A test of strategy application was used as the dependent measure for the pre-test, post-test, and maintenance test (see *Assessment Instruments*). This dependent measure asked participants to answer a guiding historical question by analyzing a given historical primary source, which was in the form of a letter. This test was paper-pencil based with a hard copy of the primary source provided and took approximately 15 minutes to complete.

Strategy Recall

The participants were also assessed on their ability to recall the purpose and identify and provide an explanation of the four levels of the SCIM strategy for historical inquiry. A test of strategy recall was used as the dependent measure in a post-test only

format (see *Assessment Instruments*). The test was paper-pencil based, consisted of two short-answer questions, and took approximately 15 minutes to complete.

Materials

The materials used in this study included the multimedia tutorial that was used to deliver the strategy instruction and four paper-pencil based assessments designed to measure participants' levels of strategy application and recall. Specifically, a pre-test, post-test, and maintenance test were used to measure participants on levels of strategy application, and a recall test was used to measure participants on the knowledge they retained regarding the purpose and four levels of the SCIM strategy.

Multimedia Tutorial

The mechanism used to deliver the strategy instruction was a CD-ROM based multimedia tutorial that was developed in Macromedia Flash. The context of the multimedia tutorial centered on the SCIM strategy for historical inquiry. The SCIM strategy consists of the following four levels of analysis: Summarizing, Contextualizing, Inferring, and Monitoring. Each level in the SCIM strategy consists of a series of questions that are utilized when analyzing a historical primary source (see Appendix A). Additionally, the tutorial was presented in two phases, which were devoted to the explanation, demonstration, and practice of the SCIM strategy.

Three different versions of the same tutorial were used, with each version representing a different combination of presentation modes used to present the instruction (i.e., animation-narration [AN], animation-text [AT], animation-narration-text [ANT]). All three versions incorporated the use of animation for the purposes of guiding student learning by signaling important information and illustrating the conceptual framework of

historical inquiry. The versions of the tutorial differed in regard to the presentation mode(s) used to present the verbal information.

The tutorial was designed according to guidelines for strategy instruction gleaned from the literature (see Table 2). Research in this area indicates that strategy instruction should be *contextual*, *direct* and *explicit*, *informed*, *scaffolded*, and provide opportunities for *practice* and *feedback* (Brown et al., 1983; Dehn, 1997; Gredler, 1997; Pressley et al., 1990). The following section describes how the multimedia tutorial was designed in accordance with these guidelines.

Evidence of Strategy Instruction Guidelines

The *context* of the tutorial is specific to the process of historical inquiry. The strategy being taught, that is the SCIM strategy, is used to analyze historical primary sources as a part of this process. *Explicit* details of what the SCIM strategy is as well as how, when, and why to use the strategy were provided to the participants during the explanation and demonstration phases of the tutorial. *Direct* explanation of those details was accomplished through the use of modeling, practice, and feedback.

The strategy instruction presented via the multimedia tutorial represented an *informed training approach*. Information regarding the significance of the SCIM strategy as well as when and why the strategy should be used was provided. Specifically, participants were told that the SCIM strategy was used in the process of historical inquiry and were instructed to use the strategy when presented a historical question and relevant primary sources in order to derive a “sensible” historical interpretation. Additionally, they were told that using the SCIM strategy would allow them to be engaged with a

primary source for a longer period of time, promote deeper level analysis and enable them to develop a historical interpretation based on evidence from the past.

The multimedia tutorial incorporated *scaffolding* in the form of modeling. An expert historian modeled the process of historical inquiry by explaining and demonstrating how to use the SCIM strategy to analyze primary sources. This modeling served as a support that allowed participants to compare their thought processes and strategy use to that of experts. The modeling was greatest at the beginning of the tutorial and was gradually diminished over the course of the instruction.

Finally, participants were provided opportunities to *practice* the SCIM strategy and receive *feedback* regarding their performance. They were presented interpretive statements, based on a given primary source, which they were to assess in terms of the statements' veracity in representing the different levels of the SCIM strategy. Informative feedback was provided in response to the participants' choices.

In addition to adhering to guidelines for effective strategy instruction, all of the versions consisted of the same structure and pacing. The *structure* of the tutorial incorporated three phases: strategy explanation, strategy demonstration, and strategy practice. The *pacing* of the tutorial involved the rate of progression from one segment to the next throughout the course of the tutorial. Each segment was approximately one minute in duration. A "continue" button appeared on each screen after the content of that segment had been presented. At that time, participants could go to the next segment; however, they could not move backwards in the tutorial or repeat a segment. The rate at which the "continue" button appeared was the same for all three treatment groups. A description of each phase of the strategy tutorial is provided in the following sections.

The percentage of time participants spent on each phase, during each day of the tutorial, is illustrated in Figure 5.

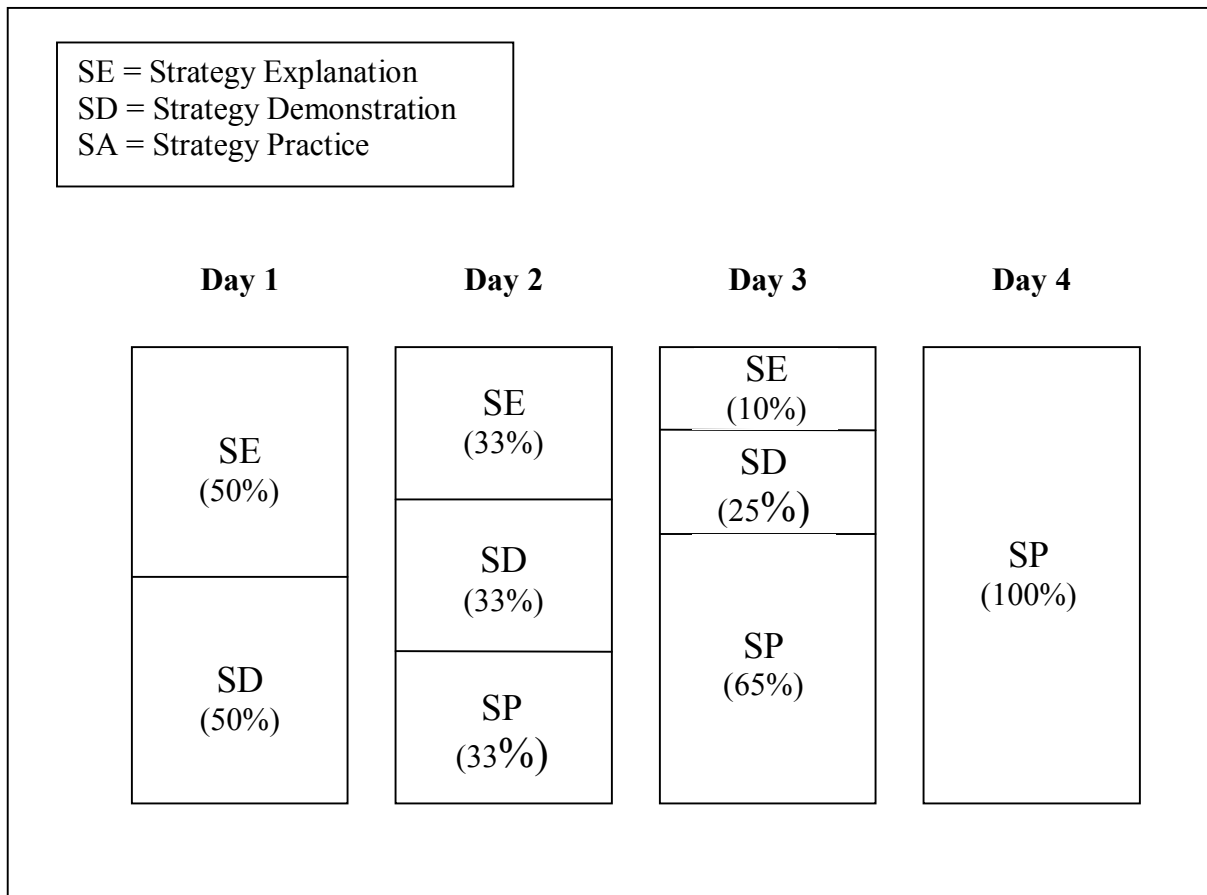


Figure 5. Percentage of time participants spent on each phase of the tutorial.

Strategy Explanation

The first phase of the tutorial consisted of the explanation of the SCIM strategy and the relevant metacognitive knowledge associated with the strategy. The purpose of this phase of the tutorial was to inform the participants of the purpose of using the SCIM strategy and why using the SCIM strategy is helpful in the process of historical inquiry. Additionally, this phase served to explain each level of the SCIM strategy and how it was used when analyzing a given primary source (see Figure 6). Half of the first day of the

tutorial was dedicated to strategy explanation, while the last day of the tutorial provided no explanation of the SCIM strategy (see Figure 5). This phase incorporated three criteria for successful strategy instruction (see Table 2): (a) an *informed approach* was utilized, (b) the information presented regarding SCIM was *direct and explicit*, and (c) the instruction was *contextual* in that it was based in the process of historical inquiry.

HISTORICAL INQUIRY

HISTORICAL QUESTIONS

S SUMMARIZING

C CONTEXTUALIZING

I INFERRING

M MONITORING

HISTORICAL INTERPRETATION

Evidence from the Source

Do we have a chance of beating the Soviets
Is there any other space program which promises dramatic results in which we could win?

Evidence from the Source

Are we working 24 hours a day
make recommendations to me as to how work can be speeded up.
Are we making maximum effort?

Interpretation / Inference

President Kennedy felt a sense of urgency to beat the Soviets in any space endeavor possible.

Following the summarizing and contextualizing phases, the next phase is the inferring phase. In answering historical questions and working with primary sources, sometimes the evidence is not explicitly stated or obvious in the source. In these cases, the evidence may be hinted at within the source and need to be draw out. This process of drawing out or creating interpretations based on information within the source is called inferring. As part of inferring we revisit initial facts gleaned from the two earlier phases and begin to create interpretations.

Continue

Figure 6. Explanation of the Inferring phase of the SCIM strategy.

Strategy Demonstration

The demonstration phase of the tutorial consisted of expert modeling of the SCIM strategy. To demonstrate how the SCIM strategy can be used to analyze primary sources, an expert modeled the process of using the SCIM strategy from the time the guiding historical question was presented to the final interpretation. The model demonstrated how

he or she progressed through each of the levels of the SCIM strategy, asking specific questions within each level (See Figure 7). The model followed this demonstration with a historical interpretation of the guiding question based on the analysis of the source provided.

HISTORICAL INQUIRY

A Letter from Bobby Murray to the Children's Bureau

Children's Bureau
Dept. of Labor
Washington, D. C.

Bobby Murray
Route 3.
Malvern, Ark.
July 8, 1939

Dear Sirs:

I write you concerning the help that is given to school children who aren't able to pay all expenses of schooling. I am a boy, fifteen years old, in the tenth grade. My only near relatives are a mother and infant niece. My sister, our only support, died last December and without some help from somewhere I will be unable to continue in school. My mother has no regular work as she has my late sister's baby to care for. My mother sews and manages to pay our living expenses. I am very anxious to continue in school and would pay my own expenses, but a boy under eighteen can't find work in our town.

Please send me the information and details as soon as possible. For proof of my school attendance write to:

Supt. J. L. Pratt
Malvern Public Schools
Malvern, Arkansas

He will tell you all you need to know. Hoping for a quick reply,

Bobby Murray
Mrs. Della Murray.

HISTORICAL QUESTIONS

S

C CONTEXTUALIZING

1. When and where was the source produced?
2. Why was the source produced?
3. What's the immediate and broader context?
4. What summarizing information can place the source in time and space?

I

M

HISTORICAL INTERPRETATION

The question of what was happening within the immediate and broader context of when and where the letter was written is interesting. The date of 1939 is significant, in a broad context. I know that 10 years earlier, in 1929, the Depression started in the United States. By 1939, however, the time of the writing of this letter, economic life was generally getting better. However, within the immediate context of Malvern, Arkansas, the letter tells me that life was still difficult, though not desperate. The author is not talking about starvation, about being thrown out of his home, or about his niece being taken away from them. Specifically, the letter tells us that unemployment was still a problem for boys under 18 years of age.

Continue

Figure 7. Demonstration of the Contextualizing phase of the SCIM strategy.

In addition to utilizing an *informed approach*, being *direct and explicit*, and being *contextual*, this phase of the tutorial incorporated *scaffolding*, which is another criteria for successful strategy instruction (see Table 2). The scaffolding in this phase of the tutorial was in the form of modeling. This phase of the tutorial was prominent on the first and second days of the tutorial and was gradually phased out as the participants progressed through each day (see Figure 5).

Strategy Practice

The practice phase of the tutorial provided participants the opportunity to practice the application of the SCIM strategy in analyzing a primary source. This phase overlapped with the strategy demonstration phase. Participants were presented with interpretive statements that they had to assess in terms of the passage's adequacy in representing the given primary source (see Figure 8). Informative feedback was provided immediately and consisted of knowledge of results and suggestions for successful strategy application.

HISTORICAL INQUIRY

<p>Directions: Consider the Monitoring phase of the SCIM strategy and examine the monitoring statements below. Then, select the monitoring statement that best represents the source.</p>	<p style="text-align: center; margin: 0;">A Letter from Bobby Murray to the Children's Bureau</p> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p>Children's Bureau Dept. of Labor Washington, D. C.</p> </div> <div style="width: 45%; text-align: right;"> <p>Bobby Murray Route 3. Malvern, Ark. July 8, 1939</p> </div> </div> <p>Dear Sirs:</p> <p>I write you concerning the help that is given to school children who aren't able to pay all expenses of schooling. I am a boy, fifteen years old, in the tenth grade. My only near relatives are a mother and infant niece. My sister, our only support, died last December and without some help from somewhere I will be unable to continue in school. My mother has no regular work as she has my late sister's baby to care for. My mother sews and manages to pay our living expenses. I am very anxious to continue in school and would pay my own expenses, but a boy under eighteen can't find work in our town.</p> <p>Please send me the information and details as soon as possible. For proof of my school attendance write to:</p> <p>Supt. J. L. Pratt Malvern Public Schools Malvern, Arkansas</p> <p>He will tell you all you need to know. Hoping for a quick reply,</p> <p>Bobby Murray Mrs. Della Murray.</p>
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Figure 8. Practice phase of the SCIM strategy.

In addition to utilizing an *informed approach*, being *direct and explicit*, and being *contextual*, this phase of the tutorial provided opportunities for *practice* and *feedback*,

which are criteria for successful strategy instruction (see Table 2). This phase was presented during the second day of the tutorial and the time participants spent practicing the application of the SCIM strategy increased each day (see Figure 5). With the exception of the application post-test and recall test, the last day of the tutorial was dedicated entirely to practicing the SCIM strategy.

Assessment Instruments

Strategy Application Test

A strategy application test was used to measure the effects of the treatments on the participants' ability to apply the SCIM strategy to analyze a primary source, in efforts to answer a guiding historical question. First, this test was utilized to measure the participants' ability to apply the SCIM strategy prior to any training (i.e., pre-test). Upon completion of the training, the strategy application test was used to assess any effects of the treatments on the participants' application of the SCIM strategy (i.e., post-test). It has been suggested that continued use of a strategy following explicit instruction serves as a form of "litmus test" for the effectiveness of the instruction (Brown et al., 1983; Pressley et al., 1990). Therefore, a strategy application test was utilized to measure the participants' continued application of the SCIM strategy a week following the completion of the training (i.e., maintenance test).

The design of the strategy application test consisted of a guiding historical question in which participants analyzed a primary source to develop a historical interpretation or "answer" to the question. Three forms of the strategy application test were used, which consisted of different guiding historical questions and different primary sources (see Appendices B-D). The order in which the participants received the three

versions of the strategy application tests was randomly assigned. The strategy application test was paper-pencil based and took approximately 15 minutes to complete. Each of the questions used on the strategy application tests were validated by expert historians.

An assessment rubric for the strategy application test was created to score the participants' responses. The rubric consisted of four sections, which corresponded to the four levels of the SCIM strategy and the questions within each level. The questions within each section correspond with a specified number of points. Participants acquired points by providing evidence of the questioning inherent in each level of the SCIM strategy. Participants had the possibility of gaining 10 points for Summarizing, 10 points for Contextualizing, 12 points for Inferring, and 12 points for Monitoring for a total of 44 points (see Appendix E). The rubric was validated by expert historians.

Two independent raters were trained on how to score the participants' responses using the assessment rubric. Several formal training sessions were held to discuss the different sections of the rubric as they related to the SCIM strategy, to provide specific examples of acceptable responses within each section, and to practice scoring responses according to the rubric. The training sessions lasted approximately two hours. Upon the conclusion of each training session, the raters were given additional responses to evaluate on their own. This process was repeated until an inter-rater reliability (r) of 0.80 had been established. Once this level of reliability had been established, the raters were directed to a web-based mechanism to grade the responses from the participants in the study. The data were stored in a database until the responses had been evaluated by both raters.

Strategy Recall Test

A strategy recall test was developed to assess the participants' knowledge of the SCIM strategy. The design of this assessment consisted of 2 short-answer questions that took approximately 15 minutes to complete (see Appendix F). Participants took the recall test on the last day of training.

An assessment rubric for the strategy recall test was created to score the participants' responses to both questions (see Appendix G). The rubric consisted of two sections, which corresponded to the two questions on the strategy recall test. The first section of the rubric was used to score responses to the question regarding the *purpose* of the SCIM strategy and was worth 10 points. The second section of the rubric was used to score responses to the question regarding the *explanation* of each level of the SCIM strategy and was worth 20 points. Participants had the possibility of gaining a total of 30 points on the strategy recall test.

Two independent raters were trained on how to score the participants' responses using the assessment rubric. A formal training session was held to discuss the different sections of the rubric as they related to each question on the strategy recall test, to provide specific examples of acceptable responses within each section, and to practice scoring responses according to the rubric. The training session lasted approximately two hours. Upon the conclusion of the training session, the raters were given additional responses to evaluate on their own. The raters were trained until an inter-rater reliability (r) of 0.80 had been established. Once this level of reliability had been established, the raters were directed to a web-based mechanism to grade the responses from the

participants in the study. The data were stored in a database until the responses had been evaluated by both raters.

Primary Sources

Primary sources are leftovers or relics of the past that come from the actual time period being studied and are used to answer questions about the past. Historical records (e.g., letters, diaries, maps) are one type of primary source. Throughout the tutorial participants were exposed to numerous historical records in the form of letters. The participants were exposed to various letters during the strategy demonstration and strategy application phases of the tutorial. The participants were exposed to a different letter each day of the tutorial and the order the letters were received was assigned randomly. Additionally, the participants had three different letters to analyze during each strategy application assessment, which were also assigned in random order.

Treatment Groups

Participants were randomly assigned to one of three treatment groups resulting in 19 participants in the animation-narration (AN) group, 19 participants in the animation-text (AT) group, and 18 participants in the animation-narration-text (ANT) group. The groups corresponded to the three levels of the independent variable (i.e., presentation mode combination). The mode used to present the visual information (i.e., animation) was identical across all three groups; however, the mode used to present verbal information varied. The following section details the treatment groups used in the study.

Group 1: Animation-Narration (AN)

Participants in the first treatment group received the strategy instruction in the form of animation and narration (n=19). The participants viewed animation that was

designed to guide their learning and signal important information regarding the SCIM strategy. They simultaneously heard narration that contained *content information*. The *content information* explained the SCIM strategy, described the processes modeled during the demonstration phase, and provided feedback during the application phase.

Group 2: Animation-Text (AT)

Participants in the second treatment group received the strategy instruction in the form of animation and on-screen text (n=19). The animation presented to the animation-text (AT) group was identical to that presented to the animation-narration (AN) group. The content information provided to this group was identical in nature but different in form. That is, the information was exactly the same, but the animation-text (AT) group received this information as on-screen text rather than spoken narration. This text was located at the bottom of the screen throughout this treatment of the tutorial.

Group 3: Animation-Narration-Text (ANT)

Participants in the third treatment group received the strategy instruction in the form of animation, narration, and on-screen text (n=18). This treatment is essentially a combination of the animation-narration (AN) and animation-text (AT) treatments. Again, the animation presented was identical to that presented in both the AN and AT groups. However, this group received the content information as both narration and on-screen text. Both modes of presentation contained exactly the same content and wording. In other words, the information presented as on-screen text was redundant to that presented through the narration. Again, the text was located at the bottom of the screen throughout this treatment of the tutorial.

Procedures

Prior to the study, informed consent was obtained in accordance with the university's Institutional Review Board (IRB). Upon approval participants were recruited and were instructed go to a designated web site to register for the study. Upon registration, the participants were randomly assigned to a treatment group and the primary sources used for each assessment and during each training session were assigned in random order. Participants signed up for a total of five 45-minute training sessions, four sessions one week and the fifth session the following week. The daily process for each day of the tutorial is detailed in the following sections.

Day 1

Upon arriving to the first training session participants were instructed to sit at a pre-assigned computer that was designated with their name tag. The computer ran the version of the tutorial that corresponded with the treatment group they had been randomly assigned to and was set up for the first day of instruction. A brief description of the purpose, procedures, and assessments of the study were presented. The participants were provided information regarding the details of the university's informed consent process and were asked to sign an informed consent form. In addition, the participants filled out a general demographics sheet which asked for their age, gender, academic level, academic major, and ethnicity. Afterwards, the participants took the strategy application pre-test.

After finishing the pre-test, the participants began the first day of training with the multimedia tutorial. Participants in treatment groups that contained narration wore headphones. During the first day of the instruction, the multimedia tutorial presented an

explanation of the SCIM strategy with a description of when and why this strategy should be implemented. Each level of the SCIM strategy and the corresponding questions in each level were discussed in detail. In addition, the participants viewed how expert models use the SCIM strategy to analyze a letter. Approximately 50% of the time was dedicated to strategy explanation and the remaining 50% of the time was dedicated to strategy demonstration. The first day of the tutorial ran approximately twenty-five minutes. The participants were dismissed after completing day one of the tutorial.

Day 2

Upon arrival, participants sat at a pre-assigned computer designated by their name tag. The computer ran the version of the tutorial that corresponded with the treatment group they had been randomly assigned to and was set up for the second day of instruction. The second day of the tutorial consisted of a multimedia presentation that was a combination of strategy explanation, strategy demonstration, and strategy practice. Participants spent approximately equal amounts of time (i.e., 33%) on each of the three phases of the tutorial. The second day of the tutorial ran approximately 20 minutes. The participants were dismissed after completing day two of the tutorial.

Day 3

Upon arrival, participants sat at a pre-assigned computer designated by their name tag. The computer ran the version of the tutorial that corresponded with the treatment group they had been randomly assigned to and was set up for the third day of instruction. The third day of the tutorial consisted of a multimedia presentation that was primarily devoted to the demonstration and practice of the SCIM strategy. Approximately 10% of the time was allotted to strategy explanation, while participants spent the remaining time

viewing expert demonstration (25%) of the SCIM strategy and practicing the SCIM strategy (65%). The third day of the tutorial ran approximately 20 minutes. The participants were dismissed after completing day three of the tutorial.

Day 4

Upon arrival, participants sat at a pre-assigned computer designated by their name tag. The computer ran the version of the tutorial that corresponded with the treatment group they had been randomly assigned to and was set up for the fourth, and final, day of instruction. The fourth day of the tutorial consisted of a multimedia presentation that was devoted to practicing the SCIM strategy. The fourth day of the tutorial ran approximately 20 minutes. After viewing the presentation, the participants took the strategy application post-test and the strategy recall test. The participants were dismissed after completing day four of the tutorial and the assessments.

Day 5

Participants took the strategy application maintenance test. Upon completion of the test, participants were thanked for their participation and dismissed.

RESULTS

Introduction

The purpose of this study was to assess the effects of strategy training, modality of presentation (i.e., modality), and redundant verbal information (i.e., redundancy) on the participants' ability to apply and recall a historical inquiry strategy. A multimedia tutorial was used to deliver instruction on the SCIM strategy for historical inquiry. Participants were assigned to one of three treatment groups which varied according to the presentation mode combinations (i.e. animation, narration, and text) used to deliver the instruction. Specifically, the instruction was presented as animation and narration to group 1, as animation and text to group 2, and as animation, narration, and text to group 3. Strategy application and strategy recall were the dependent measures.

The study employed a 1-between/1-within, 3 (Animation-Narration [AN], Animation-Text [AT], Animation-Narration-Text [ANT]) x 3 (pre-test, post-test, maintenance test) repeated measures design (see Figure 3). This design assessed the effects of training, modality, and redundancy on participant *application* of a historical inquiry strategy. Additionally, a 3 (AN, AT, ANT) x 1 (recall test) post-test-only design was utilized to assess the effects of modality and redundancy on participant *recall* of a historical inquiry strategy.

Research Questions

The study explored the impact of training, modality, and redundancy on participants' application and recall of a historical inquiry strategy. Specifically, this study sought to answer the following questions:

1. Can strategy instruction be provided effectively in a multimedia environment?

2. What are the effects of multimedia presentation *modality* on students' performance on tests of strategy application and recall?
3. What are the effects of multimedia presentation *redundancy* on students' performance on tests of strategy application and recall?

Hypotheses

The research questions presented were investigated through the use of an experimental design. The following hypotheses represent the alternative hypotheses (i.e. H₁-H₄), which indicate the predicted outcomes, as well as the null hypotheses (i.e., H₀) which were tested:

H₁: Strategy application post-test and maintenance test scores will be significantly higher than strategy application pre-test scores.

H₀: There will be no significant mean difference in strategy *application* pre-test, post-test, and maintenance test scores.

H₂: The animation-narration (AN) group will score higher on the strategy *application post-test* than the animation-text (AT) group, which will score higher than the animation-narration-text (ANT) group.

H₀: There will be no significant mean difference in *post-test* scores of strategy *application* for participants in the AN, AT, and ANT groups.

H₃: The animation-narration (AN) group will score higher on the strategy *application maintenance test* than the animation-text (AT) group, which will score higher than the animation-narration-text (ANT) group.

H₀: There will be no significant mean difference in *maintenance test* scores of strategy *application* for participants in the AN, AT, and ANT groups.

H₄: The animation-narration (AN) group will score higher on the strategy *recall post-test* than the animation-text (AT) group, which will score higher than the animation-narration-text (ANT) group.

H₀: There will be no significant mean difference in post-test scores of strategy *recall* for participants in the AN, AT, and ANT groups.

Data Analysis

The data collected included pre-test, post-test, and maintenance test scores on a test of strategy application and post-test scores on a test of strategy recall. The strategy application test consisted of one guiding historical question which was to be answered by analyzing a given historical primary source (see Appendices B-D) and was worth a total of 44 points. Two independent raters were trained how to score the application test using an assessment rubric (see Appendix E). Inter-rater reliability (r) for the application test data was .80. The strategy recall test consisted of two short-answer questions and was worth a total of 30 points (see Appendix F). The first recall test question (i.e., “What is the purpose of the SCIM strategy?”) addressed the purpose of the trained strategy and was worth 10 points. The second recall test question (i.e., “Identify and explain the four levels of the SCIM strategy.”) asked the participants to identify and provide an

explanation of the trained strategy and was worth 20 points. Two independent raters were trained how to score the recall test questions using an assessment rubric (see Appendix G). Inter-rater reliability (r) for the purpose recall data was .87. Inter-rater reliability (r) for the explanation recall data was .81.

All data were stored in a database until the conclusion of the study at which time the data were extracted, downloaded, and imported into SPSS for analysis and reporting. Among the analyses performed, the first analysis was a general descriptive analysis that reported means and standard deviations for each group condition. In addition, data were analyzed using analysis of variance (ANOVA) procedures.

Inferential Statistics

Hypotheses 1, 2, and 3 were tested using a 3 (AN, AT, ANT) x 3 (pre-test, post-test, maintenance test) repeated measures ANOVA. The Greenhouse-Geisser adjustment was used to account for any potential violation of sphericity. All p-values, therefore, were adjusted according to the Greenhouse-Geisser protocol. Hypothesis 4 was tested using a 3 (AN, AT, ANT) x 1 (post-test) ANOVA. All analyses were conducted at an alpha of .05. The following sections address the results of the analyses.

Hypotheses 1, 2, and 3

Hypotheses 1, 2, and 3 were combined for analysis purposes. The first hypothesis addressed the effects of *training* on participants' performance on tests of strategy application. Hypotheses 2 and 3 addressed the effects of *modality* and *redundancy*, respectively, on participants' performance on tests of strategy application. All three hypotheses were analyzed using the 3 x 3 repeated measures ANOVA. In addition, a

general descriptive analysis was performed that reported the means and standard deviations for each group condition for strategy application (see Table 4).

Table 4

General Descriptive Statistics for AN, AT, and ANT Groups for Strategy Application

Groups	Strategy Application ^a		
	Pre	Post	Maint
Animation-Narration (n=19)			
M	5.47	12.00	14.53
SD	2.67	8.12	6.78
Animation-Text (n=19)			
M	6.11	12.95	14.47
SD	2.83	7.67	7.66
Animation-Narration-Text (n=18)			
M	8.17	17.39	17.67
SD	4.69	7.25	8.60

Note. Values are based on strategy application test scores ranging from 1-44.

^a Pre = Pre-test, Post = Post-test, Maint = Maintenance Test

The ANOVA revealed a significant difference in the *training* within-subjects main effects analysis for strategy application, $F(2, 53) = 51.29, p = .00, partial \eta^2 = .49$ (see Table 5). There was no significant interaction between groups and tests, $F(4, 53) = 74, p = .02, partial \eta^2 = .02$ (see Table 5). Given the significant training effect, a series of post-hoc pairwise comparisons were conducted using the Bonferroni adjustment for

multiple comparisons. This analysis indicated that application post-test scores were significantly higher than application pre-test scores ($p = .00$) and that application maintenance test scores were also significantly higher than application pre-test scores ($p = .00$). However, the difference between application post-test and maintenance test scores was not statistically significant ($p = .20$). These results indicate that participants scored significantly higher on tests of strategy application following the multimedia strategy instruction.

The ANOVA did not find significance in either the *modality* or *redundancy* between-subjects main effects analysis for the groups, $F(2, 53) = 2.83, p = .06$, *partial* $\eta^2 = .09$ (see Table 4). The ANOVA, therefore, indicated that there were no significant differences in strategy application between participants in the three treatment groups (i.e., AN, AT, ANT).

Table 5

Analysis of Variance for Strategy Application by Treatment Group and Tests

Strategy Application	<i>df</i>	<i>F</i>	<i>p</i>	<i>partial η²</i>	<i>power</i>
Between Subjects					
Groups	2	2.83	.06	.09	.53
Error	53	(79.97)			
Within Subjects					
Tests	2	51.29	.00**	.49	1.00
Tests x Groups	4	.45	.74	.02	.14
Error	106	(28.36)			

Note. Values in parentheses represent mean square errors.

* $p < .05$, ** $p < .01$

The results of the 3 x 3 repeated measures ANOVA led to the rejection of the null hypothesis for H_1 ; however the null hypotheses for H_2 and H_3 could not be rejected. Specifically, participants performed better on tests of strategy application following completion of the multimedia training but there was no difference in performance between participants in the three treatment groups.

Hypothesis 4

Hypothesis 4 assessed the effects of modality and redundancy on participants' performance on a test of strategy recall. Three one-way ANOVAs were used to analyze the *total recall* scores, the *purpose recall* scores, and the *explanation recall* scores. In

addition, a general descriptive analysis was performed that reported the means and standard deviations for each group condition for strategy recall (see Table 6).

Table 6

General Descriptive Statistics for AN, AT, and ANT Groups for Strategy Recall

Groups	Strategy Recall		
	Purpose	Explanation	Total
Animation-Narration (n=19)			
M	3.26	12.68	15.95
SD	1.79	2.38	3.27
Animation-Text (n=19)			
M	3.53	11.68	15.21
SD	2.29	2.81	4.25
Animation-Narration-Text (n=18)			
M	4.00	12.56	16.56
SD	1.94	3.37	4.62

Note. Values based on strategy recall test scores with a possibility of 10 points for purpose recall, 20 points for explanation recall, and 30 points for total recall.

The ANOVA for *total recall* produced no significant difference between participants in the three treatment groups, $F(2, 53) = .506, p = .60, \text{partial } \eta^2 = .02$. The ANOVA for *purpose recall* did not reveal any significant differences between participants in the three treatment groups, $F(2, 53) = .628, p = .53, \text{partial } \eta^2 = .02$, nor did the ANOVA for *explanation recall*, $F(2, 53) = .679, p = .512, \text{partial } \eta^2 = .02$.

The null hypothesis for H₄ could not be rejected. The results of the analyses indicate that there were no significant differences in strategy recall between participants in the three treatment groups.

Analysis Summary

The results of the current study indicate that strategy application increased as a result of the multimedia strategy instruction and that the increase was maintained over time. However, the presentation mode combination (i.e. AN, AT, or ANT) used to present the strategy instruction did not have an effect on participants' performance on tests of application or recall. It can be concluded that strategy instruction can be provided effectively in a multimedia environment; however, the presentation mode combinations used to present the strategy instruction do not have an effect on strategy application or strategy recall.

DISCUSSION

Background

The goal of this study was to add to the literature on multimedia learning by examining the effects of training, modality, and redundancy on participants' ability to apply and recall a historical inquiry strategy to analyze historical primary sources. The study utilized a multimedia tutorial to provide instruction on the SCIM strategy for historical inquiry. The tutorial was designed according to guidelines for effective strategy instruction gleaned from the literature (see Table 2).

The overall effects of the *training* were assessed through a test of strategy application. Specifically, the participants were tested on their ability to apply the SCIM strategy for historical inquiry to answer a guiding historical question both before and after the multimedia tutorial intervention. In addition, the independent variable of presentation mode combination (i.e., Animation-Narration [AN], Animation-Text [AT], or Animation-Narration-Text [ANT]) was manipulated in order to assess the effects of *modality* (AN versus AT) and *redundancy* (AN and AT versus ANT) on the participants' ability to apply and recall the SCIM strategy for historical inquiry.

The subsequent discussion of the findings and subsequent conclusions is based on results from statistical analyses. The discussion on extending the findings is based on the design of effective strategy instruction and the conflicting evidence posed between the results of the present study and those of Mayer and his colleagues (Mayer & Anderson, 1991, 1992; Mayer et al., 1996; Mayer et al., 2001; Mayer & Moreno, 1998; Mayer & Sims, 1994; Moreno & Mayer, 1999, 2002) regarding the *modality effect* and the *redundancy effect*.

Results and Conclusions

All four hypotheses posed by the research study were analyzed statistically to attempt to isolate the possible significance of the training and the treatment conditions on participants' performance on tests of strategy application and strategy recall. The first three hypotheses were analyzed using a 3 (AN, AT, ANT) x 3 (pre-test, post-test, maintenance test) repeated measures analysis of variance (ANOVA). The fourth hypothesis was analyzed using three, 3 (AN, AT, ANT) x 1 (post-test) one-way ANOVAs.

The first hypothesis attempted to determine the effects of strategy *training* on participants' performance on tests of strategy application. The training main effects analysis revealed that both the participants' strategy application post-test and maintenance test scores were significantly higher than their strategy application pre-test scores. Specifically, participants were better at applying the SCIM strategy for historical inquiry to analyze a primary source in response to a guiding historical question following the instruction. In addition, the participants were able to maintain their improved level of strategy application over time. Based on this finding, it can be concluded that strategy instruction can be effectively provided in a multimedia environment.

The second and third hypotheses examined the effects of *modality* and *redundancy* on participants' performance on tests of strategy *application*. No significant differences were found in either the modality or redundancy between-subjects main effects analyses. The findings indicate that none of the treatment conditions (i.e., AN, AT, or ANT) had any differential effect on participants' levels of strategy application from pre-test to post-test to maintenance test. Therefore, it can be concluded that neither

the combination of presentation modes used to deliver the instruction (i.e., AN, AT) nor the presence of redundant on-screen text (i.e., ANT) had an affect on participants' ability to apply the trained strategy.

The fourth hypothesis examined the effects of *modality* and *redundancy* on participants' performance on a test of strategy *recall*. There were no significant differences in strategy recall between participants in the three treatment groups (i.e., AN, AT, ANT). This finding indicates that none of the treatment conditions had any differential effect on participants' levels of strategy recall. Therefore, it can be concluded that neither multimedia presentation modality nor redundancy had an affect on participants' ability to recall the trained strategy.

In summary, the results of the present study revealed two main findings. First, explicit strategy instruction provided in a multimedia learning environment resulted in significantly increased levels of strategy application and recall. Second, the combination of presentation modes used to deliver the strategy instruction did not have an affect on the participants' levels of strategy application or recall, which indicates that the predicted multimedia presentation modality and redundancy effects were not evident in this study. An explanation and the implications of these findings are discussed in the following section.

Extending the Results

Research in the area of multimedia learning has shifted from a technology-centered approach that emphasizes the capabilities of the technology, to a learner-centered approach that emphasizes how technology can be used to aid human learning. Specifically, this focus addresses the limited resource nature of working memory, dual

coding, and cognitive load (Doolittle et al., 2004). This focus has sparked years of research by Richard Mayer and his colleagues and has resulted in numerous multimedia design principles that indicate the conditions necessary for learning to occur in multimedia environments (for overview see Mayer, 2001).

The multimedia instruction in Mayer's research focused on the understanding of scientific cause-and-effect explanations. One goal of the present study was to determine if instruction focused on a different learning outcome, namely the development of a cognitive strategy, could also be provided effectively in a multimedia environment. It was hypothesized that if the intervention was designed according to guidelines gleaned from literature on strategy instruction (see Table 2), as well as principles of multimedia design (see Table 1), that participants would be better at applying a trained strategy following instruction than they were prior to the instruction. The results of the study supported this hypothesis.

Based on the significant improvement in strategy application test scores following the instruction, it can be concluded that the multimedia environment is a viable medium for the provision of strategy instruction. It has been suggested that the true effectiveness of strategy instruction is determined by the learners' continued use of a strategy following explicit instruction (Brown et al., 1983; Pressley et al., 1990). Consequently, a strategy application maintenance test was used to determine the participants' level of strategy application a week following the instruction. The results indicated that the participants maintained their improved level of performance on the strategy application maintenance test, which adds further strength to the conclusion that strategy instruction can be effectively provided in a multimedia environment.

The second goal of this study was to extend the findings from previous studies on the *modality* and *redundancy* principles. Mayer's studies focused on short (i.e., less than 3 minutes), system-paced multimedia presentations designed to teach scientific explanations (i.e., intellectual skill) which utilized animation to depict a cause-and-effect relationship. The present study differed from Mayer's studies in four respects (see Table 3). Specifically, the present study aimed at exploring the effects of modality and redundancy on a different learning outcome (i.e., cognitive strategy) while utilizing animation for a different purpose (i.e., signaling) and providing a longer (i.e., 2 hours), learner-paced presentation (see Table 3).

The independent variable of presentation mode combination (i.e., AN, AT, ANT) was manipulated to determine the effects of modality and redundancy on the dependent variables of strategy application and strategy recall. The anticipated results of the study were derived directly from previous research by Mayer and his colleagues regarding these two effects. Specifically, it was hypothesized that the group receiving the strategy instruction in the form of animation and narration (AN) in the present study would perform better on tests of application and recall than those receiving the instruction as animation and text (AT) (i.e., modality effect) and that both groups would outperform the group receiving the instruction as animation, narration, and text (ANT) (i.e., redundancy effect). However, the results of this study did not support these hypotheses and, consequently, did not reveal either a modality effect or a redundancy effect. The conflicting results revealed by the present study and prior research are explored in the following sections.

Strategies and Animation

The focus of Mayer's research was on the understanding of cause-and-effect scientific explanations (i.e., intellectual skill) with recall, matching, and transfer as the dependent variables of interest (Mayer, 2001). Specifically, his studies utilized explanations on how lightning storms develop, how car braking systems work, how bicycle tire pumps work, and how human lungs work. When presented as animation and narration, such explanations are amenable to the creation of both visual and verbal mental models depicting the process. Accordingly, Mayer and Anderson (1991), suggest that effective understanding of scientific explanations requires a mapping between visual and verbal information.

The results of multimedia studies designed to teach scientific explanations support the modality effect and redundancy effect indicating that the presentation should be delivered as animation and narration without the use of redundant on-screen text (Mayer & Anderson, 1991, 1992; Mayer et al., 1996; Mayer & Gallini, 1990; Mayer et al., 2001; Mayer & Moreno, 1998; Moreno & Mayer, 1999, 2002). The rationale behind these findings is that information is presented across both the auditory and visual channels of the working memory system without overloading either channel, thus reducing cognitive load and allowing the learner to make necessary connections between the visual depiction of the process and the corresponding verbal explanation.

In contrast to Mayer's studies, the focus in the present study was on the development of a cognitive strategy (i.e., the SCIM strategy for historical inquiry). Consequently, animation was used as a supplement to guide the participants' learning and to highlight important aspects of the strategy instruction (i.e., signaling) rather than to

present a cause-and effect relationship. Based on the results of the study, it appears that making connections between the verbal information and animation may not have been crucial to the understanding of the material (i.e., strategy instruction).

Therefore, one plausible explanation for the lack of significant differences between the presentation groups in the present study is that the animation, which was used for guiding and signaling purposes rather than explanatory purposes, did not require substantial visual processing resources. Thus, when presented with animation and visual text, the participants in the animation-text (AT) and animation-narration-text (ANT) groups were able to attend to both the animation and on-screen text presented to the visual modality without exceeding the working memory limitations of the visual processing system, which could explain the absence of both the modality effect and redundancy effect in the present study.

Building on this rationale, the lack of a redundancy effect can further be explained by the results of a study conducted by Moreno and Mayer (2002) on the effects of providing identical verbal information in both the auditory and visual modalities (i.e. verbal redundancy). In the study, students received a verbal explanation about the process of lightning formation either as narration (i.e., auditory modality) or as narration and on-screen text (i.e., auditory and visual modalities). The results of this study indicated that the group of students who received the instruction as narration and on-screen text performed significantly better on tests of recall, matching, and transfer than the group who only received narration. Thus, it was concluded that students learn better from a presentation of concurrent narration and on-screen text (i.e., verbal redundancy) than

from a narration-only presentation when no animation is presented (Moreno & Mayer, 2002).

It seems that this finding and subsequent conclusion could also be true when the animation presented is not explanatory in nature and does not require high demands on the visual processing system. In the present study, there were no significant differences found in levels of strategy application or recall between the presentation groups who received redundant verbal information (i.e., ANT) and those who were presented with only narration or on-screen text (i.e., AN and AT) in conjunction with the animation. Therefore, the results of this study suggest that participants in the ANT group appeared to be able to attend to multiple modes of visual information (i.e., animation and redundant on-screen text) and verbal information presented auditorily without experiencing cognitive overload in the visual processing system, which provides a possible explanation as to why no redundancy effect was revealed.

In summary, the difference in the desired learning outcome and the purpose of the animation used in the present study compared to that of Mayer and his colleagues present possible reasons why the hypothesized modality and redundancy effects were not replicated. Ultimately, it seems that emphasizing bi-modal, non-redundant presentation of information is less crucial for understanding when strategy development is the desired learning outcome and when animation is used as a guiding or signaling mechanism. However, it is important to note that these explanations cannot be definitively concluded from the results of the present study. Additional studies that further explore the effects of modality and redundancy on different learning outcomes and when animation is used for varying purposes are warranted.

Pace of Instruction

The present study assessed the effects of modality and redundancy by utilizing a segmented, learner-paced instructional presentation with each segment of the daily presentation lasting approximately one minute in duration. The participants had control over the pace of the instruction in that they had control over when they moved onto the next segment; however, they were not permitted to move backward in the tutorial or repeat a segment. Thus, the participants could spend as much time as they wanted with the material presented in each segment. In contrast, earlier research on the modality and redundancy effects utilized very short system-paced presentations that did not provide any breaks in the instruction. Incidentally, the modality and redundancy effects found by Mayer and his colleagues in earlier research were not replicated in the present study.

Similar results were found by Tabbers et al. (2004) in a study aimed at testing the generalizability of the modality effect. The instruction provided in the study consisted of a single one-hour training session that utilized a learner-paced presentation on an instructional design strategy (i.e., 4C/ID model). The results of this study indicated a reverse modality effect where the participants in the visual conditions (i.e., diagram plus on-screen text) scored significantly higher on tests of retention and transfer than those in the audio conditions (i.e., diagram plus spoken text).

The researchers suggested that the pacing of the instruction was the most plausible explanation for the finding of a reverse modality effect (Tabbers et al., 2004). They suggested that in learner-paced presentations, visual-only conditions are superior to bi-modal conditions because participants have more time to relate the text to the corresponding visual diagrams. Ultimately, the authors concluded that “a bi-modal

presentation is only advantageous when the system sets the pace of the instructions, whereas visual-only instructions are the preferred format if the learner is in control” (Tabbers et al., 2004, p. 80).

It is possible that allowing the learners to control the pace of the presentation results in a decrease in cognitive load on working memory because learners have the ability to process the information from one segment before being presented with new information. The additional time that is afforded for the review and processing of information in learner-paced presentations could possibly decrease the need for dual-modality, non-redundant presentations. However, this explanation can not be concluded solely from the results of the present study. Further studies are needed that compare system-paced and learner-paced presentations in addition to assessing the effects of modality and redundancy.

Length of Instruction

In the present study, participants were presented approximately two hours of multimedia instruction over the course of a four day period, which contrasts sharply with the few minutes of instruction used by Mayer and his colleagues in research on the modality and redundancy effects. This difference in the length of the instruction, which allowed the learners additional time to process, review, and practice the presented material, may have played a factor in the lack of significant differences found between the groups in the present study.

A possible rationale for this finding is that the effects of modality and redundancy fade over time due to practice. Specifically, as learners are exposed to longer periods of instruction it is possible that they are able to overcome the cognitive load that is imposed

on the working memory system as a result of uni-modal (i.e., visual-only) and redundant verbal material (i.e., on-screen text in addition to narration). Additionally, differences in extraneous cognitive load that have an influence on short learning tasks may lose their influence as more time-related factors become dominant in the learning process (e.g., practice, concentration and attention-span) (Tabbers et al., 2004).

However, these explanations cannot be definitively concluded from the results of the present study. Research is needed that examines the effects of modality and redundancy in conjunction with varying lengths of instruction. Additionally, research that assesses participants' levels of strategy application and strategy recall after each day of the instruction is needed to determine whether the effects of modality or redundancy are a factor at any phase of the instruction.

Effect Sizes

Another possible explanation for the lack of significant differences between presentation groups revealed in the present study is the extremely small effect sizes revealed through the ANOVA for strategy application (*partial* $\eta^2 = .09$) and the ANOVA for strategy recall (*partial* $\eta^2 = .02$). In contrast, Mayer (2001) reports the following median effect sizes from his studies: .84 for the modality effect of retention, .77 for the redundancy effect of retention, 1.17 for the modality effect of transfer, and 1.24 for the redundancy effect of transfer. Consequently, Mayer and his colleagues also found significant differences between treatment groups regarding the effects of modality and redundancy on recall and transfer. Therefore, based on the extremely low effect sizes revealed in the present study it can be concluded that there does not seem to be effects to find, which corroborates the lack of significant differences revealed in the statistical

analyses. Further studies that incorporate a design that would yield a larger effect might result in significance in the future. Further analyses on effect size should be conducted *a priori* to determine what effect sizes could be anticipated.

Areas of Future Research

Based on the findings of this study and the already existing body of research on multimedia design and strategy instruction, there exists much potential for the continued development and deployment of similar interventions. The significant results of the within-subjects training effects analysis indicates that strategy instruction can, in fact, be provided effectively in a multimedia environment. Consequently, exploring the conditions under which strategy development is optimized in such environments is a viable path of research. Five specific areas of suggested future research are discussed in the following paragraphs.

The literature on strategy instruction indicates that scaffolding is a necessary component for success (Dehn, 1997; Pressley et al., 1990; Rosenshine et al., 1996). According to Brush and Saye (2001), “scaffolds need to support a multitude of student issues, including data gathering and analysis, metacognitive skills, and cooperative group management” (p. 337). In the present study, scaffolding was used to support data analysis by incorporating process modeling whereby an expert historian demonstrated the process of using the SCIM strategy to analyze historical primary sources. Investigating the effects of different forms of scaffolding that address various student needs, such as the use of a student journal that assist students in determining the success or failure of their strategy use (Brush & Saye, 2002), could yield results that indicate additional ways scaffolding can be effectively incorporated into multimedia strategy instruction.

According to Bruning, Schraw, and Ronning (1999) the more an individual practices a particular skill, the better he or she gets at performing that skill regardless of initial talent and ability. However, the principle of *encoding specificity* suggests that remembering is enhanced when conditions at retrieval align with those present at encoding (Bruning et al., 1999; Driscoll, 2000). In the current study, individuals practiced applying the SCIM strategy for historical inquiry by assessing the veracity of interpretive statements and choosing the correct answer from a number of options. However, the test of strategy application used following the instruction required participants to answer a single historical question by applying the SCIM strategy to develop a historical interpretation. Ultimately, the format of the practice questions provided during the instruction was not completely aligned with the format of the question asked in the strategy application tests. Additional studies that correct this misalignment could possibly result in greater improvement in levels of strategy recall and application.

The present study utilized tests of strategy application and strategy recall as the dependent measures. The exploration of the effects of the multimedia strategy instruction on tests of transfer could provide valuable insight into the effectiveness of the instruction. Transfer is the use of prior knowledge in new contexts and is considered to be one of the most important instructional goals (Driscoll, 2000). Incidentally, Mayer has begun to emphasize problem-solving transfer as the results of various studies have indicated that “transfer is a better measure than retention when the goal is to evaluate how well learners understand a multimedia explanation” (Mayer and Chandler, 2001, p. 396). Additional studies that examined the learners’ ability to apply the SCIM strategy to analyze other

forms of primary sources (e.g., images or artifacts) could provide additional information regarding the effectiveness of the multimedia strategy instruction.

In addition to quantitative measures of understanding, the use of qualitative measures could provide pertinent information regarding the effectiveness of the instruction. In the present study, understanding was measured through tests of strategy application and strategy recall; however, nothing is known regarding the way participants' went about the process of analyzing the historical primary source. Techniques such as interviews or think-aloud procedures could provide valuable insight into the thought processes of the participants as they attempted to answer the guiding historical question by using the SCIM strategy to analyze a primary source.

Finally, further research that investigates the effects of other established multimedia design principles on strategy development is warranted. The results of Mayer's research have yielded numerous principles indicating that corresponding words and pictures or animation should be presented together in time and space (i.e. temporal and spatial contiguity principles), extraneous words, pictures, and sounds should be excluded (i.e., coherence principle), and design effects are stronger for low-knowledge and high-spatial learners (i.e., individual differences principle). Further studies should address the effects of these principles on strategy development.

Summary

In conclusion, the results of this study support the notion that strategy instruction can be delivered effectively in multimedia learning environments. However, it appears that the presentation mode combination (i.e., AN, AT, and ANT) used to present strategy instruction does not have an effect on levels of strategy application or strategy recall.

Specifically, neither a modality effect nor a redundancy effect was produced indicating that there was no difference among participants who received the instruction as animation and narration, animation and text, or animation, narration and text. Although the results did not provide the statistical significance that supports the literature on the modality and redundancy principles, the implications of the findings of the research provide several viable areas for future research.

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APPENDIX A

Levels of the SCIM strategy for historical inquiry and associated analyzing questions
(Hicks, Doolittle, & Ewing, 2004)

Summarizing (S)

1. What type of historical document is the source?
2. What specific information, details, and/or perspectives does the source provide?
3. What are the subject, audience, and/or purpose of the source?
4. What does the source directly tell us?

Contextualizing (C)

1. Who produced the source?
2. When, why, and where was the source produced?
3. What was happening locally and globally at the time the source was produced?
4. What summarizing information can place the source in time, space, and place?

Inferring (I)

1. What is suggested by the source?
2. What conclusions may be drawn from the source?
3. What biases are indicated in the source?
4. What contextualizing information, while not directly evident, may be suggested from the source?

Monitoring (M)

1. What is missing from the source in terms of evidence that is needed to answer the guiding historical question?
2. What ideas, images, or terms need further defining from the source in order to understand the context or period in which the source was created?
3. How reliable is the source for its intended purpose in answering the historical question?
4. What questions from previous stages need to be revisited in order to analyze the source satisfactorily?

APPENDIX B

Strategy Application Test (1)

Directions: Historical primary sources may be used to assist in answering historical questions. Using the source provided, answer the following historical question:

Question: What role did missionaries play in Native American/American Indian communities in the late 19th century?

Source:

Fort Lapwai
July 20th 1891

Dear Mrs. Maxwell,

Through all of this long silence think I may say you have not been forgotten for one day. 1st I had to be in fashion and have LaGrippe. It passed from the soldiers among the poor people leaving many among, young & old to linger weeks or months & die. A number are yet suffering from it, they are weak scroffulus lungs making them an easy prey.

Every year there must be two great gatherings upon the reserve. Strange they should get their ideas about having a happy time (4th July) from King Georges Men 'Hudson Bay Co!' There was nothing new in the whole exercises (to me) except a council which Miss Fletcher called to decide by ballot if Nez Perces would adopt certain Indians who are among them and wish to be allotted here. One case a difficult one. The Indian woman not objected to but two of her six children were as well as her unprincipled white husband who had bribed some of the leading Indians to carry the matter through & so defeat Mrs. F. who knew the heart of the order loving Nez P. I have always admired Mrs. F. but had never seen her strong character so tested before or her ability to checkmate wily Indians politicians. It is said she receives a Congressmans salary. She earns it. She meets the old medicine men in councils who have tried to kill her with a look. She knows no fear & so fully understands Indian character. She cannot be taken by surprise & withal she is very lovable. Our work is one (civilization and religion).

I thank you in their stead for the kindly greetings. Please give much love to your husband, your children, fathers & sisters. Reserve a prayer for your own dear self. God's blessing upon you and His cause.

Loving yours, Kate C. McBeth.

APPENDIX C

Strategy Application Test (2)

Directions: Historical primary sources may be used to assist in answering historical questions. Using the source provided, answer the following historical question:

Question: What were the conditions in farming communities on the Great Plains in the early 20th century?

Source:

Dear Sister and Family:

Marion, Nebraska, Aug 3rd, 1911.

Your welcome letter rec'd Mon. and we were real glad to hear from you again, but sorry to hear that the crops were so complete a failure. but you are not alone in that, and there will be lots of people see harder times in this country this winter than they have for yrs. The merchants in all of the towns are cutting off the credit system, and I dont know what some will do. we have a good prospect for some corn. but the grasshoppers have cleaned up some fields and damaged them all more or less, and there has been a number of hard hail storms all around us. and you know what all of that means to the corn, and the last pest now is what is supposed to be the army worm. they are thick as they can be on the ninth divide dont know if they have crossed the creek yet. they seem to work on the thistles and weeds principally and people that claim to know say that if we get rain enough to keep them green they won't go in the corn.

We have had some nice rain lately, one night before last and another last evening. This is a pretty decent country when we have rain. if only the crops could be like they ought to. the ground is going to be in fine shape for wheat if it keeps on raining

The girls had a letter from Lillie yesterday. she was enroute to New York City, has signed with a new Co. I believe at better wages. Orville Woods seen Gus a short time ago in Frisco. He expects to be running an airship for another man after while. at present he was getting \$125 per mo. as a chauffer for a private family. would like to have Lillie back if she would come, but she says she wont go till she has saved some money.

Love to all. Ever your sister

Estella

APPENDIX D

Strategy Application Test (3)

Directions: Historical primary sources may be used to assist in answering historical questions. Using the source provided, answer the following historical question:

Question: How were women's rights viewed in the 19th century?

Source:

P. W. Daivis,
1850,

New Harminy, IL., Sept. 20,

I have long noticed, with great pleasure, that women here are induced by their education to study all subjects; that they are not frightened from certain topics by the fear of being called "blue stockings," or "female pendants;" and I have hoped, and still have some hope, that men here, unlike the generality of the men of England, have faith that a woman of cultivated intellect, capable of depending on her own exertions, may make a loving wife, a trusty partner, and a mother worthy to be trusted with the important charge of offspring. I have some fear that the principal advance in this respect, in this country, is a universal respect for female talent as a source of national pride; but that men, even men of sound knowledge in other respects, are so miserably deficient in knowledge on this subject, are such bad observers effects in every way surrounding them, that they prefer taking to their bosoms the pretty creature whose ignorance makes her dependent, and whose submission is mistakenly calculated on as being more certain because she cannot reason on her duties, or on how to promote the best happiness of life.

I care not for that education which gives merely literary talent; I covet that which gives independence of thought, which will fit a woman to examine all subjects before she adopts a belief regarding them, and which will enable her to assert an unpopular opinion, if her convictions lead her to hold that opinion rather than any other. Truth can exist only in such a course; intellect can have a healthy action only in such a course; and it is only the women who can do this that will be mothers of independent, honest, and intellectual sons. I earnestly hope to find many such women in the United States.

With much respect for yourself, and for the other ladies engaged in the good cause.
I am, my dear madam, Yours sincerely,
Margaret Chappelsmith

APPENDIX E

Strategy Application Test Assessment Rubric

Summarizing	10 points
Contextualizing	10 points
Inferring	12 points
<u>Monitoring</u>	<u>12 points</u>
Total	44 points

Summarizing:

What type of historical document is the source?

What specific information, details, and/or perspectives does the source provide?

What is the subject and/or purpose of the source?

Who was the author and/or audience of the source?

Criteria	Points		Examples
1. Does the student mention the <i>type of source</i> , or indicate that the type of source is not clear?	0 Pts	No	
	2 Pts	Yes	
2. Does the student indicate the <i>subject</i> of the source, by providing specific details from within the source?	0 Pts	No	
	2 Pts	Yes	
3. Does the student indicate the <i>audience</i> for the source, or that the audience is unknown?	0 Pts	No	
	2 Pts	Yes	
4. Does the student indicate the <i>purpose</i> of the source, or that the purpose is not clear?	0 Pts	No	
	2 Pts	Yes	
5. Does the student indicate the <i>author</i> of the source, or that the author is not clear?	0 Pts	No	
	2 Pts	Yes	
Total:	10 Pts		

Contextualizing:

When and where was the source produced?

Why was the source produced?

What was happening within the immediate and broader context at the time the source was produced?

What summarizing information can place the source in time and place?

Criteria	Points		Examples
1. Does the student indicate <i>when</i> the source was produced, or that this information is not available?	0 Pts	No	
	2 Pts	Yes	
2. Does the student indicate <i>where</i> the source was produced, or that this information is not available?	0 Pts	No	
	2 Pts	Yes	
3. Does the student indicate <i>why</i> the source was produced, or that this information is not available?	0 Pts	No	
	2 Pts	Yes	
4. Does the student indicate what was happening in the <i>immediate context</i> of when/where the source was produced?	0 Pts	No	
	2 Pts	Yes	
5. Does the student indicate what was happening in the <i>broader context</i> of when/where the source was produced?	0 Pts	No	
	2 Pts	Yes	
Total:	10 Pts		

Inferring:

What is suggested by the source?

What interpretations may be drawn from the source?

What perspectives are indicated in the source?

What inferences may be drawn from absences or omissions in the source?

Criteria	Points		Examples
1. Does the student <i>draw explicit inferences</i> based on evidence within the source?	0 Pts	No	
	4 Pts	Yes	
2. Does the student <i>draw implicit inferences</i> based on evidence within the source?	0 Pts	No	
	4 Pts	Yes	
3. Does the student draw <i>explicit inferences</i> based on <i>absences</i> or <i>omissions</i> in the source?	0 Pts	No	
	2 Pts	Yes	
4. Does the student draw any inferences based on <i>perspectives</i> within the source?	0 Pts	No	
	2 Pts	Yes	
Total:	12 Pts		

Monitoring:

What additional evidence beyond the source is necessary?

What ideas, images, or terms need further defining from the source?

How useful or significant is the source for its intended purpose in answering the historical question?

What questions from the previous stages need to be revisited in order to analyze the source satisfactorily?

Criteria	Points		Examples
1. Does the student identify the need for information beyond the source?	0 Pts	No	
	2 Pts	Yes	
2. Does the student indicate the need to further define elements of the source?	0 Pts	No	
	4 Pts	Yes	
3. Does the student provide an evaluation of the usefulness or significance of the source?	0 Pts	No	
	4 Pts	Yes	
4. Does the student attempt to clarify or expand on questions previously addressed during the analysis?	0 Pts	No	
	2 Pts	Yes	
Total:	12 Pts		

APPENDIX G

Strategy Recall Test Assessment Rubric

Question 1	10 points
Question 2	20points
Total	30 points

Question 1: What is the purpose of the SCIM strategy?

Criteria	Points		Examples
1. Develop a better understanding of history	0 Pts	No	
	2 Pts	Yes	
2. Engage in historical inquiry	0 Pts	No	
	2 Pts	Yes	
3. Investigate and respond to guiding historical questions	0 Pts	No	
	2 Pts	Yes	
4. Evaluate historical sources	0 Pts	No	
	2 Pts	Yes	
5. Develop historical interpretation	0 Pts	No	
	2 Pts	Yes	
Total:	10 Pts		

Question 2: Identify and explain the four levels of the SCIM strategy.

Criteria	Points		Examples
1. How many levels of the SCIM strategy does the student identify?	0 Pts	Identifies none	
	1 Pts	Identifies 1 phase by name	
	2 Pts	Identifies 2 phases by name	
	3 Pts	Identifies 3 phases by name	
	4 Pts	Identifies 4 phases by name	
2. Does the student provide a detailed explanation of Summarizing?	0 Pts	No details	
	2 Pts	Yes, basic idea	
	4 Pts	Yes, detailed response	
3. Does the student provide a detailed explanation of Contextualizing?	0 Pts	No details	
	2 Pts	Yes, basic idea	
	4 Pts	Yes, detailed response	
4. Does the student provide a detailed explanation of Inferring?	0 Pts	No details	
	2 Pts	Yes, basic idea	
	4 Pts	Yes, detailed response	
5. Does the student provide a detailed explanation of Monitoring?	0 Pts	No details	
	2 Pts	Yes, basic idea	
	4 Pts	Yes, detailed response	
Total:	20 Pts		

VITA

Andrea L. McNeill

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EDUCATION

- Ph.D. Curriculum and Instruction: Instructional Technology, December 2004
Virginia Polytechnic Institute and State University, Blacksburg, VA
- M.S. Education: Computers in Education, May 2001
Shenandoah University, Winchester, VA
- B.S. Kinesiology: Athletic Training, May 1996
James Madison University, Harrisonburg, VA
- Teacher Health Education/Physical Education, NK-12, May 1997
Licensure James Madison University, Harrisonburg, VA; Shenandoah University,
Winchester, VA

PROFESSIONAL EXPERIENCE

- 2003 Course Manager, Department of Teaching and Learning
Virginia Polytechnic Institute and State University, Blacksburg, VA
- Collaborated with course designers to evaluate and improve the design of online technology courses
 - Managed course delivery through the use of a course management system (i.e., Blackboard)
 - Communicated with students to troubleshoot problems
 - Assessed performance and assigned grades
- 2002-2003 Web Designer, Department of History
Virginia Polytechnic Institute and State University, Blacksburg, VA
- Managed the design and development of a series of web-based instructional modules for university-level U.S. History courses
 - Collaborated with professors to evaluate the design and effectiveness of instructional modules
 - Designed and created graphics for use in web-based modules

- 2002 Technology Lab Assistant, Department of Teaching and Learning
Virginia Polytechnic Institute and State University, Blacksburg, VA
- Served as a member of a team of graduate assistants to maintain the educational technology lab
 - Provided technical support for the College of Human Resources and Education
- 2001-2002 Instructional Technologist, Department of Teaching and Learning
Virginia Polytechnic Institute and State University, Blacksburg, VA
- Designed, developed, and conducted technology training for pre-service teachers
 - Provided technical support for the development of on-line portfolios
 - Secured facilities and resources for workshops
- 1997-2001 Health Education/Physical Education Teacher
Sherando High School, Stephens City, VA
- Independently and cooperatively designed, developed and implemented curriculum for Health and Physical Education classes
 - Developed lesson plans and supporting instructional materials
 - Effectively organized time, space and resources for instruction
 - Managed classroom of 25-30 students, effectively instructing and evaluating learning while maintaining discipline
- 1997-1998 Athletic Trainer
Sherando High School, Stephens City, VA
- Evaluated, treated, and managed athletic injuries for students participating in interscholastic sports
- 1996-1997 Exercise and Rehabilitation Technician
Winchester Physical Therapy and Sports Medicine, Winchester, VA
- Collaborated with physical therapists and athletic trainers to develop orthopedic rehabilitation protocols
 - Implemented and oversaw orthopedic rehabilitation of patients
 - Assessed and recorded patient progress

PUBLICATIONS

Doolittle, P. E., McNeill, A. L., Terry, K. P., & Scheer, S. B. (2004).
Multimedia, cognitive load, and pedagogy. In S. Mishra & R. C. Sharma
(Eds.) *Interactive Multimedia in Education and Training* (pp. 184-212).
Hershey, PA: IDEA group.

Terry, K. P., Doolittle, P. E., Scheer, S. B., & McNeill, A. (in press).
Principles for the use of multimedia in higher education pedagogy. *Journal
of Excellence in College Teaching*.

TECHNOLOGY SKILLS

- Web Development: Dreamweaver, HTML
- Programming and Authoring: Director
- Graphics: Photoshop, Paint Shop Pro, Animation Shop
- Video: I-movie, Media 100
- Miscellaneous: Office, Windows 9x, 2000, XP

LICENSES AND CERTIFICATION

- 2000- Collegiate Professional Teaching License, Virginia State Board of
Education
- 1997- Certified Athletic Trainer, National Athletic Trainers' Association Board of
Certification

PROFESSIONAL AFFILIATIONS

- 2002- Association for the Advancement of Computing in Education (AACE)
- 2001- Instructional Technology Student Association (ITSA)
Co-President, 2002-2003
- 2001- Association for Educational Communications and Technology (AECT)
- 2001- Eastern Educational Research Association (EERA)