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Exploration of concise redundancy in online multimedia learning

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AN EXPLORATION OF CONCISE REDUNDANCY IN ONLINE MULTIMEDIA LEARNING

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ABSTRACT

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With the rapid growth of multimedia in education, the importance of investigating the effect of redundancy, repeating instructional messages to enhance conceptualization in instructional material design, is becoming more important. Various studies have been conducted recently regarding the effects of different forms of redundancy. A multimedia lesson presenting concurrent on-screen text, still graphics or animations, and narration is a typical setting in redundancy research.

Concise redundancy is the revision of the on-screen text into a concise form which is presented to the learners concurrently with visualizations and narration. The purpose of this study was to investigate, while controlling for spatial ability, the effects of concise redundancy on students' retention and confidence when learning with highly complex multimedia materials. In addition, the effects of animation or still graphics along with text redundancy were examined.

No significant differences were found between the graphic presentations (animation or series of stills) and text redundancy groups (full, concise, or none) on retention or levels of confidence. When examining the results taking into account high and low spatial abilities, no significant differences were found in terms of different graphic presentation (animation or series of stills) and different text redundancy groups

(full, concise, or none). However, in one condition, low spatial ability learners exhibited significantly higher levels of confidence than high spatial ability learners when learning with narrated static graphics and concise redundancy.

The current study should provide further guidance for researchers who are interested in examining narrated multimedia lessons containing concise redundancy when comparing static graphics to animated graphics.

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CHAPTER I

INTRODUCTION

A term “golden age of multimedia” has been used to describe the progress of the past two decades in educational technology (Lohr & Gall, 2004). Even though multimedia enriched leaning environments may be expensive to create (Choi & Clark, 2006), the number of these environments is rapidly expanding. Multimedia contains features that simultaneously deliver non-verbal information (i.e., sounds, images, motion pictures, and animations) and verbal information (i.e., written text and spoken text). With these features, acquiring information becomes more efficient and multifaceted. From a learning perspective, the value of multimedia is even greater because learning can be enhanced by the variety of stimuli that multimedia provides.

The field of multimedia learning has become a rapidly emerging discipline in the past ten years. Generally speaking, learning occurs when instructional content is delivered utilizing the features that only multimedia can fulfill. That is, learners receive visualizations, sounds, and verbal information through the multimedia learning process thus enabling them through the construction of mental representations (i.e., cognitions) of the information. When this happens, the idea of the old Chinese proverb “a picture is worth a thousand words” becomes a reality in learning. Consequently, multimedia instruction is capable of promoting learning by involving verbal and pictorial information simultaneously. This simultaneous modality is what Paivio (1971) has referred to as Dual Coding theory.

Paivio's Dual Coding learning theory serves as a fundamental principle for practice and development in the area of instructional design, especially in computer-mediated, multimedia learning. He explained that when one prompt (i.e., the verbal) is forgotten, another (i.e., the visual) may help trigger recall. Dual-coding learning theory is based on the assumption that two different symbolic systems serve different parts of the learning process in human memory and cognition. One of these two systems involves verbal information while the other involves non-verbal information (Paivio & Lambert, 1981). There is substantial evidence in the literature supporting the proposition that learning is enhanced from instructional design based on dual channel coding (Paivio, 2009).

Problem Statement

Often computer mediated instruction is created by individuals with little or no training in instructional design. Consequently, they may be unaware of the theory related to the instructional design. These individuals rarely apply theory-based learning principles (e.g., cognitive load learning theory, dual-coding theory and principles for multimedia learning). Instead they often use computer programs that are designed for creating "quick lessons" (Evans, 2008). Many of these programs are designed to provide online lecturing video streams along with online readings or graphics. Even though the essential idea of multimedia learning is promoting learning by involving visualizations and text, these types of lessons do not take advantage of multimedia principles. As the related literature shows, teaching and learning with multimedia is not that simple. Because there is a lack of instructional design expertise, and because principles of multimedia design are often not followed, student achievement does not reach its full potential. This study attempted to maximaize the potential of multimedia principles in order to enhance learning.

Mayer (2009) in his principles for multimedia learning claimed that animation improves learning when used adequately. In Moreno & Mayer’s study (2002b), subjects in the animation group demonstrated higher achievement on retention and transfer tests than those in the non-animation group. However, the results may not necessarily be attributed to an animation effect. The levels of complexity of the animated materials should also be examined. Tversky and her colleagues (2002) argued that animation cannot be considered as effective for learning when the content can be conveyed by static graphics (i.e., series of pictures). The use of animation may not be necessary because static graphics provide enough conceptual images for learning. In addition, if the animated material is highly complex or involves much detailed information, animation may not be not effective because it produces cognitive overload on the learners.

In a study conducted by Schmidt-Weigand and his colleagues (2010), subjects were presented with concurrent text (written text, or spoken text) and visualizations. By tracking eye-movements, they observed that participants in the written text group did not give priority to visualizations. Instead their attention was drawn to the concurrent on-screen text. Further, when the subjects were given extra time, they still did not focus their attention on the visualizations; rather they continued to focus on the text. Although the participants in the written text group spent more time than those in the spoken text group, they performed similarly on retention, transfer and visual memory tests. The tracking of eye-movement revealed that the concurrent text drew more attention than the visualizations. The complexity of the material would be a possible factor that affected participants' attention.

Another area of study that relates to learning with multimedia concerns the learners' level of confidence. In a study conducted by Tsai (2006), level of confidence was found to be an important factor when participants were presented with redundant multimedia materials. As a result, the researcher also examined level of confidence to determine whether it was related to multimedia learning.

Rationale of the Study

According to Dual coding theory (Paivio, 1971) and principles for multimedia learning (Mayer, 2009), increasing the modality of the learning materials when applied to instructional design has been shown to be an effective strategy to enhance learning. However, because of the lack of formal training, when more modality is applied, it is often confusing for the learner and results in negative learning outcomes. Splitting learning materials into different modalities may produce redundant information for learners (Diao & Sweller, 2007). For example, a typical format of redundancy is narrating the learning content while presenting the same information as on-screen text. Learners have to split their attention to skim through the presented text while listening to the narration. They are required to put forth more mental effort to compare what they read with what they hear. This is shown in the literature where researchers have reported the negative effect of redundancy (Diao & Sweller, 2007; Dowell & Shmueli, 2008; Kalyuga, Chandler, & Sweller, 2004; Moreno & Mayer, 2002b). Thus, learning may be hindered by increasing identical information which has been repeated in different formats (i.e., redundant texts or visualizations) (Mayer, 2009). Instruction should exclude redundant information to help learners achieve better performance (Kalyuga, Chandler, & Sweller, 1998).

Mayer and his colleagues (2001) conducted a series of experiments studying the effect of redundancy for multimedia learning. During earlier investigations, they introduced the redundancy principle for designing multimedia lessons. Students taught with graphics, narrations and on-screen text (i.e., the script of narration), performed worse than students taught with narration and graphics. This observation was consistent with the assumption that redundant information increases cognitive load and reduces the learning performance. The attrition of students' cognitive load was observed when students spent attention on skimming through the on-screen text while listening to the narration. Later, similar results were observed by Moreno and her colleagues (2002b) when applying animation instead of still graphics with redundant on-screen text.

The following methods have been used to deliver information to learners: (a) segmenting redundant information (Jamet & Le Bohec, 2007), (b) written or spoken emails (Dowell & Shmueli, 2008), and (c) using on-screen animated agent assistance (Craig, Gholson, & Driscoll, 2002). These methods have been employed in various subject areas: (a) language learning (Diao & Sweller, 2007), (b) scientific topics (Leahy, Chandler, & Sweller, 2003; Moreno & Mayer, 2002a, 2002b), and (c) skills to operate/control devices (Seagull, Wickens, & Loeb, 2001). In each case, concurrent text did not work well with narration. It appears that within either the verbal or non-verbal systems, when more information is loaded into working memory, less information is perceived; therefore, learning is hindered.

Concise Redundancy (CR)

When text is used for computer mediated instruction, it can be revised into a shortened form and presented as concise text. When combined with visualizations such as still graphics, diagrams, or animations, the result is called concise redundancy (CR). Mayer & Johnson (2008) conducted a study containing a revised form of on-screen text (i.e., shortened text that were derived from the original narration scripts), still graphics, and narration. The use of revised text produced better achievement among students. Students in the revised-text group (i.e., graphics-narration-revised-text) outperformed both the graphics-narration group, and the graphics-narration-full-text group. The results indicated that the integration of graphics and narration along with CR in designing instructional materials may help students achieve the goals of the lesson more effectively. Dowell & Shmueli (2008) indicated that presenting a shortened visual text should be the next step in redundancy investigation. Thus, the need for conducting a study integrating CR including more variables such as animation and students' mental abilities of understanding instructional materials is important for educational research. In the current study, the researcher is referring to a combination of using concise form, visualizations, and narration as concise redundancy.

Purpose of the Study

The purpose of the study sought to further document the features of concise redundancy (CR). Combining animated materials as an instructional feature with CR has yet to be conducted. It would be worthwhile to document the relationship between using animations in instruction and the inclusion of CR in a multimedia learning environment. Furthermore, including learner characteristics such as spatial abilities, levels of confidence, and gender are factors that can help to guide this area of research.

Statement of Research Questions

In order to better investigate the effect of concise redundancy, a series of research questions were proposed.

Q1 Does the type of graphic presentation (animation or series of stills) and text redundancy (full, concise, or none) have an effect on factual retention when controlling for spatial ability?

Q2 Does spatial ability (high or low) have an effect on factual retention when given a presentation utilizing one type of graphic (animation or series of stills) and one type of text redundancy (full, concise, or none)?

Q3 Does the type of graphic presentation (animation or series of stills) and text redundancy (full, concise, or none) have an effect on student level of confidence when controlling for spatial ability?

Q4 Does spatial ability (high or low) have an effect on student level of confidence when given a presentation utilizing one type of graphic (animation or series of stills) and one type of text redundancy (full, concise, or none)?

Limitation of the Study

Limitations in education research are unavoidable. This is study was limited by the following factors:

First, there were a limited number of participants. All of the sample participants were located within one Rocky Mountain area university. Subjective conclusions might occur due to the small number and limited diversity of the participants when attempting to generalize the results of this study to other populations (e.g., different aged learners, students in different major, students who are native speakers of different language, etc.).

Second, a random selection of participants is relatively difficult for educational research (Ary, Jacobs, & Razavieh, 2002; Fraenkel & Wallen, 2000), which may suggest a limitation for the present study.

Third, interactions and previous contacts among participants might affect the test and survey responses. In order to reach more participants, the experimental settings, tests and surveys of this study were designed in an online format. Even though it was online, participants may have been classmates in other online or face-to-face courses at the university. This could cause some contamination of the survey and test-score data.

The fourth limitation is related to pre-existing knowledge of the content. Some knowledge in the instructional content designed for the present study might be already known or be familiar to some participants. Therefore, test scores from these participants may be affected.

Fifth, the lesson content and activities were difficult. The multimedia lesson was intentionally designed to be complex to investigate a higher order animation effect related to concise on-screen text design while simulating an authentic online learning environment. The difficulty and complexity of the entire lesson might result in poor performance of students and result in an unclear outcome when analyzing the proposing effects.

The sixth limitation was the possibility of students becoming fatigued during the course of the treatment. Their experience of a one-hour complex multimedia activity might mentally overload their working memory. Students may have been mentally tired after taking the spatial ability test and watching the videos. As a result, the scores on the retention test may have been adversely affected.

Definition of Terms

Multimedia learning: Multimedia learning usually refers to learning process which involves computer mediated instructions, CD-ROMs or the Internet with text, pictures, audio, animations or videos. However, according to Wiley and Ash (2005), it is a narrow interpretation of multimedia learning. According to Mayer (2005), learning that requires the learner to "build mental representations from words (such as spoken text or printed text) and pictures (such as illustrations, photos, animation, or video)" can be categorized as multimedia learning (p. 2).

Multimedia instruction: (or multimedia learning environment) Instruction that involves pictures, text, sound or animation to promote learning.

Verbal materials: Instructional materials that are presented with the form of spoken words or written words. For example, narration, on-screen caption, text, pictorial words, etc.

Non-verbal materials: Instructional materials that are presented in the form of sounds, images, or animations rather than verbal forms. For example, pictures, illustrations, music, animations, etc.

Redundancy principle: The term comes from the observation that learning is improved when less repeated materials are included (i.e., graphics and narration is better than graphics, narration, and text) (Mayer, 2009).

Concise redundancy (CR): A concise form of redundant on-screen text which presents only important and necessary information rather than the whole text of the corresponding narration script.

Educational technology (termed also Instructional Design and Technology): With the most recent definition of educational technology (Richey, 2008) approved by the Association for Educational Communications and Technology (AECT), the field of educational technology has moved into a new stage. The new definition states that "educational technology is a study and ethical practice of facilitating learning and improving performance, by creating, using, and managing appropriate technology resources and processes" (p. 25).

Cognitive ability: Cognitive ability refers to several types of cognitive abilities such as verbal ability, imagery ability, and spatial ability that are usually used to help or inform academic or employment decisions. Among these predictors, educational researches has recognized the measurement of spatial ability as a more effective factor in predicting student achievement (Carroll, 1993).

Cognitive load theory (CLT): A limited working memory is assumed by CLT which asserts instruction should be designed within the capacity of learners' working memory in order to achieve optimal learning outcome. Recent cognitive researches use intrinsic, extraneous, and germane cognitive load to categorize types of cognitive load for a better identification and application of instructional design and strategy (Paas, Renkl, & Sweller, 2003).

CHAPTER II

REVIEW OF LITERATURE

The purpose of the present chapter is to explore the literature related to multimedia learning with a focus on concise redundancy. With the goal of finding theoretical and empirical support for the present study, this chapter begins from a broad view addressing the history and background of cognitive learning-related psychology and theories, and ends with a conclusion that points to the needs and purpose of the present study – concise redundancy (CR). Thus, the chapter is divided into four sections, and each section is more specific.

1. Cognitive psychology: The first section discusses the origins, major milestones, and current state of cognitive psychology.
2. Cognitive learning theories:
    a. Cognitive load learning theory
    b. Dual-coding learning theory
    c. Information processing theory
3. Mayer's multimedia learning principles.
4. Review of studies in redundancy-related instructional design for learning: introduces a brief history of redundancy study and the CR rationales.

Cognitive Psychology

To know, or to become acquainted with is the original meaning of cognition in its Latin form, *cognoscerer*. “All our mental abilities – perceiving, remembering, reasoning, and many others – are organized into a complex system, the overall function of which is termed *cognition*” (Glass, Holyoak, & Santa, 1979, p. 2). To study human cognition is the psychology aimed at understanding human intelligence and how the mind works – *how* to know (Wickelgren, 1979). More specifically, examining the “mental processes” is study of cognitive psychology (Robinson-Riegler & Robinson-Riegler, 2004).

An overview of the history of cognitive psychology is often referred to as the development of methodology in psychology (Jones & Elcock, 2001). In the 1880’s, German psychologist Wilhelm Wundt introduced an introspective method to investigate consciousness – an examination of the self’s own mental state (Hothersall, 1984). The assumption was that one’s conscious state was reportable through carefully-controlled self-observation, which was later termed structuralism by Edward Bradford Titchener (Roback, 1964). Structural psychologists began the first psychological laboratory and were recognized as the founders of early experimental psychology (Misiak & Sexton, 1966). However, the method of introspection was less valid because the data were unobservable and not reproducible which led to subjective and unreliable results (Takala, 1984). Schultz and Schultz (1996) also pointed out that the problem with the approaches of structural psychology to consciousness was that the mind was ignored, making human subjects more like mechanical recording instruments. This could be another reason that introspective psychology was not broadly accepted in America.

Later, influenced by Darwin's theory of evolution, William James began another school of thought which asserted that the occurrence of consciousness represented continuous processes of mediation between mental needs and the situation – a pragmatic point of view – which was known as *pragmatism* (Pickren & Dewsbury, 2002). The thought, as a result, led the discussion of human cognition to that consciousness should be seen as a continuous state and should not be analyzed as individual parts (James, 1918). Similarly, John Dewey (1896) argued that rather than studying the neural circuitry of the reflex arc as chemical reactions among the receptors and effectors, they should be seen as a continuous, integrated, and adaptive phenomenon in an organism. Their thoughts then constituted the core rationale of functional psychology, commonly known as *functionalism* (Leahey, 1987). In contrast to *structuralists* who investigated what was consciousness (i.e., what features were included), functionalists focused on the question of how did consciousness work (Smith, 1993). Therefore, the methodology gradually changed from subjective introspection (i.e., structuralism) to objective observation (i.e., observable behaviors). As a result, *behaviorist* psychology soon prevailed (Benjamin, 2007). In 1920, John B. Watson led a revolution in American psychology. He asserted that psychology should concentrate entirely on observable behaviors, which was known as behaviorism.

Watson (1930) stated:

> The subject matter of human psychology is *the behavior of the human being*…behaviorism claims that consciousness is neither a definite nor a usable concept…the Behaviorist, who has been trained always as an experimentalist, holds further that belief in the existence of consciousness goes back to the ancient days of superstition and magic. (p. 2)

Rooted in the doctrine of the functionalists, who maintained that consciousness and behaviors should be seen as a whole that one uses to adapt to the environment, behaviorists believed that outward behaviors represented the only standard for examining consciousness. In other words, observing consciousness was insignificant when studying behaviors (Benjamin, 2004). Therefore, rather than human subjects, animal subjects served their purposes for their methodology. Behaviorists focused only on performed behaviors (i.e., responses) under sets of controlled stimulus, and then concluded general patterns for human behaviors from studying the relationships among stimuli – response – reinforcement (Jones & Elcock, 2001). Ivan Pavlov (1927), the author of the *Conditioned Reflexes* (i.e., which was well known as *classical conditioning*), stated that, “It is obvious that the different kinds of habits based on training, education, and discipline of any sort are nothing but a long chain of conditioned reflexes” (p. 395).

Due to the attention on observable behaviors, behaviorism contributed considerably to developing theories of learning strategy. For example, O’Neil (1979) explained that the field of instructional design grew rapidly because of the advent of Instructional System Design (ISD), which was primarily a method for developing curriculum for industry and military training. Based on the behaviorists’ point of view, the evaluation component in ISD focused on observable learning outcomes. Mager’s *Preparing Behavioral Objectives* (1962) for instructional design was another example of the use of behavior-emphasis. He proposed an ABCD model for preparing objectives for instructional design. He defined A – Audience, B – Behavior (performance), C – Condition, and D – Degree (criterion). Thus it can be seen, behavioralism has provided an observable approach for examining the effectiveness of learning.

Due to its strong effect on teaching and learning, behaviorism dominated psychology for nearly half of a century (King, Viney, & Woody, 2009). It became mainstream in America, thereby excluding other schools of thought that studied the internal processes of the human mind (Robinson-Riegler & Robinson-Riegler, 2004). Neisser (1967), who was one of the earliest cognitive psychologist, reflected on behaviorists in his book:

> For them, it is legitimate to speak of stimuli, responses, reinforcement, and hours of deprivation, but not of categories or images or ideas…a generation ago, a book like this one would have needed at least a chapter of self-defense against the behaviorist position, today, happily, the climate of opinion has changed, and little or no defense is necessary. (p. 4)

During the 1970's, the attention in psychology gradually shifted from observable behaviors to unobservable mental processes (Benjamin, 2004). Since then, the psychologists began to emphasize the human mind which has become a dominant paradigm for learning and experimental psychology (Best, 1986). Among scholars, history has recognized George Miller and Ulric Neisser as two of the most important researchers in the early stage of cognitive psychology development (Schultz & Schultz, 1996). Miller labeled the study of psychology in cognition in the following quote:

> In using the word "cognition" we were setting ourselves off from behaviorism… we wanted something that was mental – but "mental psychology" seemed terribly redundant…"common-sense psychology" would have suggested some sort of anthropological investigation, and "folk psychology" would have suggested Wundt's social psychology…what word do you use to label this set of views? We chose "cognition". (Baars, 1986, p. 210)

Neisser (1967) gave a definition for the processes involving *cognition*, "…by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used…cognition is involved in everything a human being might possibly do" (p. 4).

Using this definition, cognitive psychology enables the exploration on how information is processed in the human mind and provides the framework to understand the mechanism that triggers the mind to know and to perform. These are critical functions that promotes teaching and learning (Gagné, 1985). Anderson (1990) added a clear explanation for the purpose of studying in cognitive psychology:

> The desire to understand is an important motivation for the study of cognitive psychology, as it is in any science, but the practical implications of the field constitute an important secondary motivation…if we really understand how people acquire knowledge, intellectual skills and how they perform feats of intelligence, then we will be able to improve their intellectual training and performance accordingly. (pp. 3-4)

Cognitive psychologists adopted scientific approaches, and began to consider internal mental states (i.e., motivation and confidence) that were opposite to the assertion by the behavioralists. Major developments in later cognitive-originated studies have turned a new page in cognitive psychology. For example, the concept of the human mind as an information-processing system (IPS), the progress of artificial intelligence, and development in linguistics, are all facets of the "Cognitive Revolution" (Royer, 2005).

Combining the consideration of human factors (i.e., placing emphasis on human skills and performance) and concepts in information theory (i.e., defining a framework to understand the unseen transfer of information), Donald Broadbent (1958) suggested that the mind is analyzable if it can be studied as an information-processing system (IPS). The concept of IPS based on the cognition of the human mind was widely accepted and then inspired the field of *cognitive science* (Leahey, 1987). The advancement in artificial intelligence is a significant example of the IPS approach (Berger, Pezdek, & Banks, 1987). Based on the assumption of IPS, these researchers claimed that the human mind can be simulated by a computer program. The use of artificial intelligence has been verified and developed throughout many fields of study, especially in interactive technology (Sternberg & Pretz, 2005). Simon and Newell (1962) proposed that the human thinking process can be simulated by computer programs. For example, simple tasks such as playing chess with computers or more complex tasks, such as operating a simulated airplane flight program. They stated that the approach using computer programs to simulate human thinking can be:

> …regarded as theories, in a completely literal sense, of the corresponding human process…these theories are testable in a number of ways, among them, by comparing the symbolic behavior of a computer so programmed with the symbolic behavior of a human subject when both are performing the same problem-solving or thinking tasks. (p. 138)

The third significant field advanced by cognitive psychology was linguistics. Noam Chomsky (1972) constructed a series of approaches in language learning. He first announced his theory of transformational grammar, and then proposed his theory for universal grammar. He proposed these linguistic theories which yielded to the perspectives of consciousness and claimed that language acquisition and performance are ruled by certain sets of universal phonetics, semantics, and syntax in the human brain. He further pointed out the essential connection between language and the human mind by stating that, “Language is a mirror of mind in a deep and a significant sense…it is a product of human intelligence, created anew in each individual by operations that lie far beyond the reach of will or consciousness” (Chomsky, 1975, p. 4).

Above all, the rapidly growing understanding of cognition is the basis of understanding other sub-disciplines within learning psychology (Haberlandt, 1994). Currently, cognitive psychology along with artificial intelligence, computer science, linguistics, and philosophy have formed the multi-disciplinary field of cognitive science (Dawson, 1998).

Cognitive Learning Theories

Cognitive Load Theory

Cognitive load theory focuses on the limitations of human working memory to determine the effectiveness of instruction (Sweller, van Merrienboer, & Paas, 1998) which has been recognized as a framework for research in cognitive process and instructional design (Paas, Renkl, et al., 2003). The theory suggests that instruction should be designed within the capacity of working memory in order to achieve optimal learning outcomes (Kirschner, 2002).

Working memory can be described as little pieces of information a learner can temporarily retain in the mind while simultaneously allowing instant access to the newer or additional acquisition of information (Cowan, 2005). Sweller and his colleagues (1998) asserted that working memory can be regarded as consciousness. Information is not perceivable until it is brought into the learner's working memory because it is only viewable in the working memory. Experiments used to investigate the capacity limits of working memory have indicated that an amount of three to nine chunks of information can be simultaneously stored in the working memory (Cowan, 2001; Miller, 1956). Baddeley & Hitch (1974) demonstrated that working memory, controlled by a central executive function, used phonological loops and visuo-spatial sketchpads to process information. These phonological loops were capable of holding speech-based information and the visuo-spatial sketchpads were capable of dealing with visual information.

Information is held in the working memory enabling processing and manipulating for compilation of more complex tasks such as comprehension or reasoning (Baddeley, 2000). The term *load* can be equated to *effort*. Thus cognitive load can be referred to as the required mental effort to process or transfer a quantity of information at one time. When the presented information is beyond the amount of mental effort the learner can offer, working memory may be overloaded and learning is limited. On the other hand, when the presented information is too little, then the mental effort consumed by the learners is less, therefore learning is inefficient (Cook, 2006). Too little information does not engage learners in a way to restructure their existing memory to incorporate the new information and store for future usage (Lohr, 2008). Long-term memory is the place where the information stored for being used in the future. It employs mass number of schemas — "cognitive constructs that incorporate multiple elements of information into a single element with specific function" (Paas, Renkl, et al., 2003, p. 2).

Researchers have recently begun to examine measurements for cognitive load (Paas, Renkl, et al., 2003; Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Xie & Salvendy, 2000). For this purpose, cognitive load is split into three forms: intrinsic load, extraneous load, and germane load. Detailed descriptions are as follows:

Intrinsic Cognitive Load

Intrinsic cognitive load refers to the mental effort that reflects on the number of elements/concepts, level of difficulty, and complexity of the instructional content. A more element-involved, difficult, or complex content requires higher intrinsic cognitive load for learning to occur. Intrinsic load cannot be influenced by instructional designers due to the nature of the materials and the learners' expertise (Paas, Renkl, et al., 2003). However, reducing intrinsic cognitive load can directly reduce overall cognitive load (Tindall-Ford & Sweller, 2006). Careful instructional design can accomplish this overall reduction.

Extraneous Cognitive Load (Ineffective Cognitive Load)

Extraneous cognitive load refers to the mental effort expended on components or elements that do not directly add to the instructional content. This can be controlled by instructional designers (Kalyuga & Sweller, 2004). In other words, poorly-designed instruction can increase extraneous cognitive load and decrease available working memory. Presenting text and related illustrations separately in space or in time can impose extra effort to working memory and consequently increase extraneous load (Mayer, 2009).

Germane Cognitive Load (Effective Cognitive Load)

Germane cognitive load refers to the extra effort devoted by the learners to facilitate learning (Paas, Renkl, et al., 2003). Increasing germane load for learning is meaningful only when the total cognitive effort of the learners (i.e., the sum of the intrinsic and the extraneous load) is not overloaded (i.e., exceeding the learner's cognitive capacity). Therefore, using appropriate instructional design such as chunking, segmenting or sequencing materials, or scaffolding the concepts can increase the cognitive load of the learners while facilitating construction and automation of schemas (Paas, Tuovinen, et al., 2003).

Since the assumption of the three forms of cognitive load are additive, the goal of instructional design is to minimize the extraneous load, and optimize the intrinsic load, so that more working memory can be released for germane load within the cognitive capacity limits. Extraneous cognitive load is the mental effort imposed by poor instructional designs, whereas germane cognitive load is the effort needed for further learning (Kirschner, 2002). Researchers prefer to term germane load as essential load because enhancement of knowledge acquisition is inevitable for learning such as asking learners to self-explain about course content after class (Kalyuga, 2007).

Information Processing Theory

The Magic Number Seven

Information processing theory (IPT) proposed by Miller (1956) suggested two concepts describing how information was processed and stored. One concept involved “chunking” which implied that humans could temporally hold five to nine units of information at one time (i.e., seven minus two or plus two) in short-term memory based on reviewed experiments. These units could be any form of chunked information such as sets of numbers, words, shapes, or positions. The concept of chunking and limited capacity of the short-term memory was rooted firmly in later cognitive learning theories.

The TOTE Unit (Test-Operate-Test-Exit)

The second concept proposed by Miller and his colleagues (1960) was the mechanism of TOTE unit. According to them, the stimulus-response principle proposed by behaviorists should be replaced by the TOTE unit when describing how information is processed and stored in the human brain. In one TOTE unit, if the test results appeared that input information could not pass the test because certain conditions were needed to be modified, an operation automatically occurred to change the condition toward the test, and then the unit performed a second test. The TOTE cycle continued until the test was passed (i.e., comprehension of the new information; or construction of schemas) or exited (i.e., unnecessary information). However, when information exited the particular TOTE unit that did not necessarily mean the information was aborted, in contrast, the information might be sent to a higher hierarchic TOTE unit for a higher level of testing conditions, which could be understood as approaching the end or the goal. (See Figure 1.)

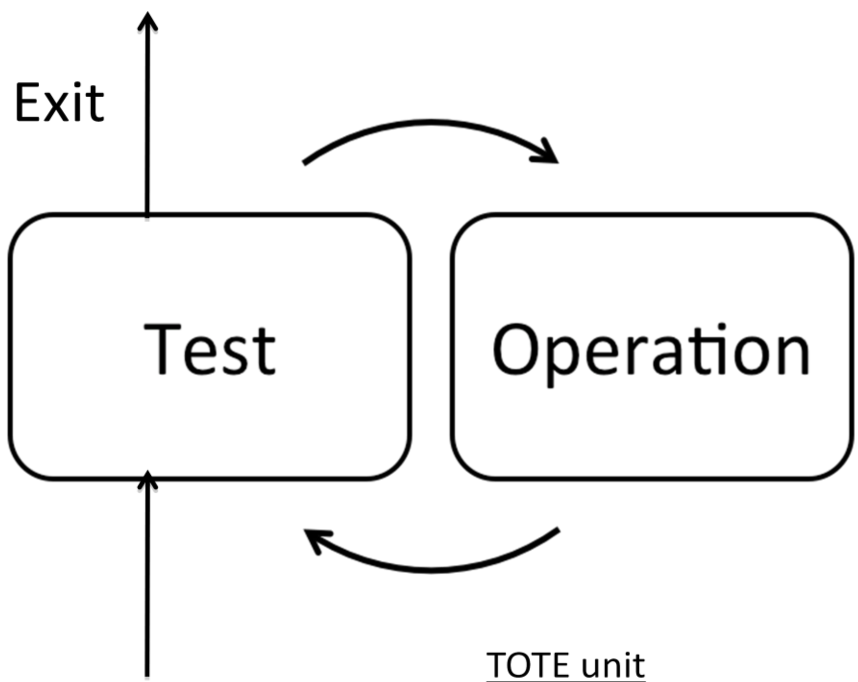

*Figure 1.*TOTE unit.

Information processing theory holds three assumptions. First, the IPT suggests that five to nine (i.e., seven plus or minus two) chunks of information approximates the capacity of short-term memory. Second, as a means between short-term memory and long-term memory, the TOTE unit mechanizes how information is processed and stored. Third, human cognitive structure can be built hierarchically (Miller, 1956; Miller, et al., 1960).

Stage-Theory Model

A widely accepted demonstration of information processing theory was the stage-theory model (R. C. Atkinson & Shiffrin, 1968). Assumptions of discontinuous and multi-stages of learning and memory were the key elements of this model. The stage theory demonstrated three stages of memory: sensory memory, short-term memory, and long-term memory. (See Figure 2.)

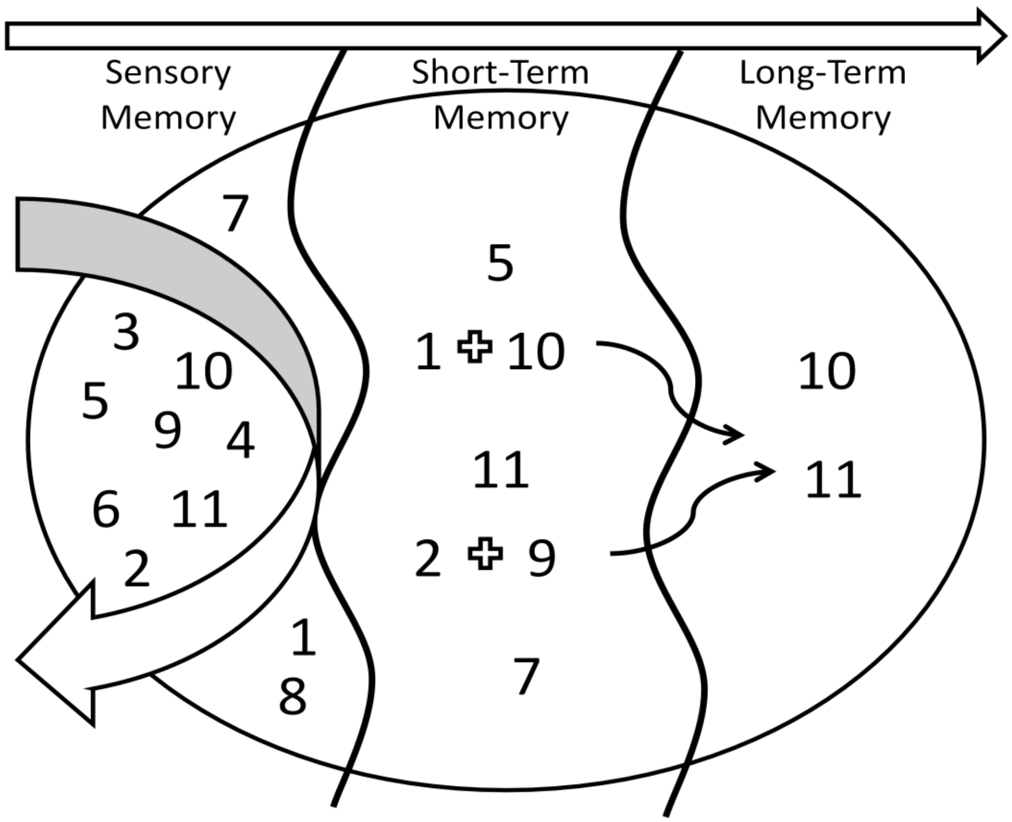

Figure 2. Information processing theory, stage theory model.

Sensory Memory. Sensory memory selects information entries based on specific sensors such as hearing, seeing, and other kinds of sensual perceptions. Stimuli that are not perceived in the sensory memory stage would not be processed to the next stage.

Information is only held for a short period of time in this stage of memory: approximately a half second for the visual stimuli and three seconds for the auditory stimuli. Thus, the sensory memory becomes critical for learning because sensors act as the only entrance for all new information. According to Driscoll (2005), “attention” and “automaticity” can be two key elements to improve sensory memory.

Learning is enhanced when the learners’ attention is drawn to all the given information. Although only limited information could be received due to the limitation of human sensory ability; however, through training, the automaticity of reception of sensory stimuli could be improved. For example, after much practice, a worker may not need to pay full attention to the number change on the computer screen while still listening to job-related readings from different sources.

Working Memory (Short-Term Memory). Sensory memory and working memory are both categorized as short-term memory. After the new information is perceived by the sensors, the new information is processed and stored in the second stage, the working memory. In this stage human memory holds the information for fifteen to thirty seconds and begins to lose it if the brain does not have further interaction with it.

Generally, according to the model, rote or maintenance rehearsal helps keep the information longer in short-term memory. However, merely rehearsing information, while the short-term memory is still in-taking new units may help the information last longer; however, it will still gradually be forgotten and will only hold a certain amount of the information unit (i.e., the capacity of four to nine units of information in the short-term memory). Therefore, a processing strategy is needed to incorporate new information to the existing memory structure. To chunk or segment information is recognized as the most effective method to increase memory in this stage. For example, the method of chunking can be referred to as grouping the information into smaller units (i.e., chunk a phone number from 424424424 to 424 – 424 – 424), or to segment the information subsequently (i.e., separate the information and memorize pieces one after another), or to make sense of the information with meaningful representations (i.e., memorizing information with mnemonics skill).

Long-term memory. Long-term memory has been recognized as infinite in terms of its capacity for memory. However, the most challenging task is to move information from working memory to long-term memory. In addition, without meaningful practice or rehearsal of the new structured information, decay of the long-term memory would still occur. For learning new information, long-term memory must be in a dynamic state and keep communication with short-term memory (Ericsson & Kintsch, 1995).

It is still unknown to scholars how information is stored in long-term memory. However, there are ways of storing memory we may observe from human thinking patterns. The first type is categorization. Bruner and his colleagues (1986) observed children's oral language acquisition and suggested in scaffolding theory that the minds categorize information as a means for perceiving, conceptualizing, learning, and making decisions. Scaffolding is giving students required guidelines, rules, hints, or techniques during or before giving the contents. As an application in instructional design, scaffolding plays a role to assist categorizing to solidify learning. Thus, categorization is one of the patterns to store information in long-term memory. Scholars also suggested other patterns of memory such as episodic memory (i.e., personal living experiences or events remembered in the mind), semantic memory (i.e., general abstract concepts), procedural memory (i.e., procedural knowledge), and imagery memory (Gagne, Yekovich, & Yekovich, 1993; Goleman, 1995; Paivio, 1971).

In summary, the stage-theory model for information processing theory suggests that there are three discontinuous stages in human memory when acquiring new information. The first stage is the sensory memory which contains the most limited-capacity. The second stage is the short-term memory which holds a longer temporal capacity with seven minus or plus two units of memory. The third stage is the long-term memory which holds, theoretically, unlimited capacity for memory. Information processing theory serves as the bedrock to support later cognitive related theories. Dual-coding theory, cognitive load theory, and multimedia learning theory are applications of the information processing theory, and form the framework for this study.

Dual Coding Theory

Paivio's Dual-coding theory (1986) is a widely accepted form of demonstrating how information is perceived and processed in the brain, particularly for learning. He explained that:

> Human cognition is unique in that it has become specialized for dealing simultaneously with language and with nonverbal objects and events. Moreover, the language system is peculiar in that it deals directly with linguistic input and output (in the form of speech or writing) while at the same time serving a symbolic function with respect to nonverbal objects, events, and behaviors. Any representational theory must accommodate this dual functionality. (p. 53)

Dual-coding learning theory is based on the assumption that two symbolic subsystems serve different parts of the learning process. One subsystem processes nonverbal information (i.e., visual, audio, or pictorial cognition) while the other processes verbal information (i.e., speech, text, and related linguistic cognition) (Paivio & Lambert, 1981).

Paivio suggested that these two subsystems are independent of each other, but partially interconnected. The independency implies that in addition to each of the subsystems operating independently, they are also activated by the visual or verbal sensors independently. For example, if one hears, “The trip we had last summer,” the brain can recall the images about the trip last summer without a description of words. The recall of the memory can be done merely by visual stimulus, and it is not necessarily stimulated by verbal process. Secondly, the two subsystems are partially interconnected which means that each of the two subsystems can activate processes between them. For example, when one reads about the trip of last summer, the words will mentally bring up the images of that trip.

Paivio termed each representational unit in the verbal subsystem as “*logogen*”, and the unit in the nonverbal subsystem as “*imagen*”. It is assumed by the theory that *logogen* processes language related information, verbal entities, associations and hierarchies. *Imagen* is used in pictures, mental images, part-whole relationships (i.e., environments), and usually can be connected to verbal information. To illustrate, the *logogen* unit is used to process verbal information, where the verbal presentation is usually constituted in logical sequences (i.e., smaller units are processed before larger units, or sub units are processed before concluding units). In contrast, *imagen* process does not seem to be constrained by the logical sequences because images do not necessarily need to be perceived sequentially (i.e., they can be individual images without relationships).

The part-whole concept implies that when the perceived *imagen* is a specific and recognizable part of a whole (i.e., the eyes as the part of a face), the parts other than the eyes (i.e., ears, nose, and mouth) would be simultaneously seen and perceived synchronically in the mental image. Similarly, the face could be a part of a bigger image as well. According to Paivio (2007), nonverbal information seems to be more easily and rapidly switched to encoded information among parts and wholes. As a result, it can be comprehended more rapidly than verbal processes because the pictorial information is encoded directly with both images and words (i.e., both the verbal and nonverbal channel), whereas the verbal information can only be processed in the verbal channel. The old Chinese proverb "a picture is worth of a thousand words" is based on a similar rationale.

Clark and his colleague (2004) pointed out that there are three representational connections when processing stimulus between the verbal and nonverbal subsystems: representational, associative, and referential connections.

The representational connection is the first and direct activation by external verbal or nonverbal stimuli to each subsystem (i.e., verbal-related connections activated by verbal stimuli; nonverbal-related connections activated by nonverbal stimuli). For example, when one reads the word *dog*, it activates a verbal symbol *dog* in the mind. The associative connection then activates connections to related verbal or nonverbal subjects in the mind within each subsystem (i.e., verbal stimuli elicits associative words; nonverbal stimuli elicits associative images or sounds). For example, the word *dog* elicits related words such as *puppy*, *pets*, *animals*, *Golden Retriever*, and so forth. The referential connection activates connections within or between each subsystem (i.e., verbal stimuli elicits verbal or nonverbal symbols in mind, and nonverbal stimuli elicits verbal or nonverbal symbols in mind). For example, the word *dog* elicits related words, images of dogs, and sounds of dogs; similarly, a picture of dogs elicits the word *dog* and related subjects in the mind.

Because of the importance of referential connections which occur when verbal or nonverbal stimuli enter one's consciousness, dual-coding theory suggests that a more efficient strategy to enhance memory would be when both the verbal and nonverbal subsystems are simultaneously involved in learning (Paivio & Lambert, 1981).

Multimedia Learning Principles

Mayer began to develop principles for the design of multimedia instruction using seven principles (2001), then progressed to ten principles (2008), and more recently to twelve principles (2009). Based on nearly two decades of experiments in investigating learners' cognitive activities in multimedia lessons, Mayer finally concludes that there are twelve principles for the design of multimedia instructions. The proposed principles are: (a) coherence, (b) signaling, (c) redundancy, (d) spatial contiguity, (e) temporal contiguity, (f) segmenting, (g) pre-training, (h) modality, (i) multimedia, (j) personalization, (k) voice, and (l) image. (See Table 1)

Table 1. Progress of Multimedia Learning Principles

	(Mayer, 2001)	(Mayer, 2008)	(Mayer, 2009)
1	Coherence		
2	Spatial Contiguity		
3	Temporal Contiguity		
4	Modality		
5	Multimedia		
6	Redundancy		
7	Individual Difference	Personalization	
8		Signaling	
9		Segmenting	
10		Pre-training	
11			Voice
12			Image

Coherence Principle

Learning is enhanced when extraneous information is excluded rather than included. Extraneous materials can be referred to as non-related interesting or unneeded words, pictures, sounds, and symbols. Extraneous materials can result in “attrition” of working memory, or distracting learners from important messages, or may interfere with the assimilation of the presented information, and they may also direct learners to an irrelevant conclusion regarding the presented information. However, opposite views held by researchers emphasize a positive effect on interesting but unimportant information incorporated in instructions which are often called the “seductive details effect” (Muller, Lee, & Sharma, 2008). Further, they claimed that it is less difficult to control the effect of “seductive details” investigations within the laboratory setting, but more difficult in the real world online or multimedia settings (Mitchell, 1993; Schraw & Lehman, 2001).

Signaling Principle

Learning is promoted when the structure of the lesson or the highlight of the key points are presented as cues (i.e., headings for different sections, voice emphasis on key words, or introductory sentences). Signaling can help guide learners to key elements, therefore reducing possible extraneous paths when learning with multimedia lessons. To support this view, Ozcelik, Arslan-Ari and Cagiltay (2010) conducted an experiment by changing heading colors and tracking eye movement to observe the signaled effect. The results showed that the signaled group outperformed the non-signaled group on transfer and matching tests.

Redundancy Principle

Learning is improved when less repeated materials are included (i.e., graphics and narration is better than graphics, narration, and text). Extraneous mental effort has been observed when learning with graphics, narration, and on-screen text simultaneously. According to Mayer, the visual channel of the audience is overloaded because the pictures and on-screen text is competing for cognitive resources. In addition, learners may need to wait for the spoken narration while reading the on-screen text because the speed of listening is usually slower than reading (Guan, 2009). Further discussions regarding the redundancy effect are addressed in the next section for the history of redundancy related studies.

Spatial and Temporal Contiguity Principle

Learning is enhanced when corresponding text and pictures are arranged closely to each other rather than further from each other. For example, a geographical graphic and its related explanation should be presented near to each other. When corresponding pictures and words are presented closely, learners will use less mental effort due to this proximity and thus will increase their retention of the information. In contrast, learning will be reduced when corresponding pictures and words are presented further from each other. Learners will use more mental effort in bringing the information together. Early investigation regarding the spatial contiguity effect can be traced to the report by Tarmizi and Sweller (1988) stating that reducing “split-attention” leads to a better result in mathematical work examples.

Learning is improved when corresponding text and pictures are presented to learners simultaneously rather than sequentially. Mayer mentions that “mental connections” are the keys when text and pictures are presented simultaneously. This concept also echoes the assumption of *referential connections* in the Dual Coding theory. When they are presented simultaneously, learners are more likely to be able to assimilate both sources (i.e., verbal and nonverbal) in their working memory thus building a better mental connection in their minds. In contrast, presenting text and pictures one after another may retard learning because learners need to hold parts of the information in working memory while waiting for the next entry, which may delay or lessen their ability to build mental connections in their minds.

Previous studies regarding the spatial and temporal contiguity effect have been well-documented. A meta-analysis based on fifty related studies conducted by Ginns

(2006) reported that, except for low-element-interactivity materials (i.e., less complex contents), the closer the instructional design fits the spatial and temporal contiguity, the better the performance gain while learning high-interactivity materials (i.e., more complex contents).

Segmenting Principle

Learning is enhanced when materials are segmented and learners have control of the presentation pace. An animated multimedia lesson may be overwhelming when the presentation is continuous and learners do not fully understand one or more of the steps within it. Learners must create corresponding mental connections to integrate presented multimedia information in order to learn (Schnotz & Bannert, 2003). When they are still thinking about the previous scene, the next scene is playing. Thus, learning is more likely to be improved by segmenting the materials and providing control of the presentation pace to the users.

Lusk, et.al. (2009) pointed out that effectiveness of segmentation of the materials might be related to individual differences (high and low working memory differences) of the learners. In their study they proved that low-working memory students performed equal to high-working memory students on segmented multimedia lessons. Moreno (2007) found that although the multimedia group (video and animation) underperformed the non-multimedia group on retention test, they outperformed on evaluation and applied skills. Within the multimedia groups, the segmented group reported a lower level of cognitive load and outperformed the non-segmented group on all measures.

Pre-Training Principle

Learning is improved when learners have pre-training regarding names and characteristics in the materials as compared to having no pre-training. Literature defines pre-training as the process to help learners obtain prevision of task specific knowledge (Nelson & Cheney, 1989). According to Mayer, *casual mode* and *component mode* occurs in a learner's cognitive process while receiving multimedia presentations. The *causal model* is a systematic procedure that learners construct mentally when the presentation is addressing procedures (i.e., the procedures to install the Internet system at home). The *component model* is a naming process that learners use in order to mentally tag names on the key parts in the procedure (i.e., router, modem, internet protocols, etc). When learners are given pre-training for names or characteristics of key-parts of the procedures, learning is more efficient.

In addition to Mayer's approach to pre-training in multimedia learning, various methods of pre-training/interventions were found beneficial in education: physical education (Pooley, 1972; Wiegand & Everhart, 1994); science education (Toh, Boo, & Yeo, 1997); educational psychologist program (Monsen, Brown, Akthar, & Khan, 2009); and computer education (Pauli, May, & Gilson, 2003). It is worthwhile to note that in Pauli and his colleagues' investigation, a computer game which was unrelated to the instructional content was used as a pre-training tool, and they observed an improved performance on the learning spreadsheet application even for low-MCP learners, indicating pre-training using computer games can be beneficial for low MCP learners. Scale of microcomputer playfulness (MCP) suggests an individual trait on personal "imaginative, non-serious, or metaphoric manner so as to enhance intrinsic enjoyment, involvement, and satisfaction" on learning computer-mediated materials (Glynn & Webster, 1992, p. 85). Therefore, for learners who do not use computers regularly (i.e., low-MCP learners), a pre-training can improve the effectiveness of the multimedia lesson.

Multimedia & Modality Principles

The multimedia principle suggests that learning is enhanced when the instructional materials are presented both in words and pictures in contrast to using words alone. To illustrate, when words and pictures are both presented, learners are more likely to build mental connections in both visual and verbal systems. When only text is presented, learning is less likely to occur than when using both the visual and verbal systems. As an application of dual-coding theory (Paivio, 1969), the multimedia principle echoes the model of representational, referential, and associative connections conceptualized in the mind.

In addition to the multimedia principle, the modality principle suggests that learning is promoted when narrations and visualizations are presented simultaneously as opposed to when on-screen text and visualizations are presented (i.e., narration is better than text). On-screen text and visualizations both go through the visual channel when one is perceiving information. Rather than letting two different visual materials overload one channel (i.e., the visual channel), making the on-screen text audible would "off-load" the visual channel and enable the audio material to be more readily processed by a different channel. In the mean time, the visual channel could more fully process the information presented by the pictures/animations.

Literature shows that eye-movement tracking is increasingly used to study instructional material design, particularly concerning multimedia and modality effects

(Hyona, 2010; Mayer, 2010; Schmidt-Weigand, et al., 2010). In the first two articles, the authors give commentaries on current eye-movement tracking studies for the multimedia learning environment. The third article reveals interesting results by tracking the fixation time spent by learners switching attention between visualizations and on-screen text (i.e., modality effect). The authors found that learners gave priority to on-screen text over the visualizations in the system-paced condition; moreover, they spent more time on the text when given extra time. On the other hand, students in the self-paced group fixated first and fixated for a longer period of time on the visualizations. This finding was consistent with Mayer's modality principle. Mayer (2010) commented that the freedom of pace-control over the multimedia lesson might be the reason that the modality effect was not significant in the study.

Personalization Principle

Learning can be improved by giving spoken content in conversational style rather than formal style. Informal, and first or second-person language such as, "Today, we are going to practice 3D drawing software together," as opposed to formal language, "The lesson demonstrates guidelines for 3D drawing software," can help to achieve higher learning outcomes. In the literature, the application of informal tones such as dialogue style instructions showed that dialogue-like learning environments promote deeper social engagement (Beck & McKeown, 1996; Craig, Sullins, Witherspoon, & Gholson, 2006).

Based on the possible benefit provided by the conversational effect, Clark and Mayer (2003) claimed that applying the personalized principle for integrating the pedagogical agent is particularly important for multimedia learning. According the research, pedagogical agents are

> …lifelike autonomous characters cohabit learning environments with students to create rich, face-to-face learning interactions… can demonstrate complex tasks, employ locomotion and gesture to focus students' attention on the most salient aspect of the task, and convey emotional responses to the tutorial situation." (Johnson, Rickel, & Lester, 2000, p. 1)

However, studies regarding pedagogical agents provided average comments (Craig, et al., 2002). In addition, instructions that using the personalization principle within the pedagogical agent did not always yield similar contributions to learning. In a web-based instructional study, Bruce and his colleagues (2006) applied the personalized principle to teach chemistry with a pedagogical agent. They observed a significant improvement through the use of pedagogical agent but not favorable effects with the personalized pedagogical agent. They conjectured that the animated pedagogical agent did serve to improve learning, but it seemed to interfere with the personalized effect.

Voice Principle

Learning is enhanced when the narration is presented using a human voice rather than a synthesized voice (i.e., computerized voice). The suggestion of voice principle accompanied with pedagogical agent effect are based on *social agency theory* (Mayer, Sobko, & Mautone, 2003), which proposes that learning is in a "quasi" conversation with computers (e.g., the more social interaction occurs, the better learning maybe enhanced). "Once the social conversation schema is activated, learners are more likely to act as if they are in a conversation with another person" (p. 419). Thus, learning with a human voice in a multimedia lesson is more likely to outperform the computer voice (R. K. Atkinson, Mayer, & Merrill, 2005). In addition, using female voice is not found to be more advantageous than using male voice (Harrison & Atkinson, 2009).

Image Principle

Although pedagogical agent studies suggested that presenting multimedia lessons with an on-screen animated or human speaker may enhance learning. Mayer, in his image principle, suggested that learning is not necessarily improved when the image of the speaker is presented on the screen. Rather than a fine design of an animated agent or videotaping of a human face, image principle suggested that a “simpler” on-screen pedagogical agent with dynamic gesturing or signaling may better assist learning. Theoretically, when the image of the speaker or the animated agent is shown on the screen, the learners may expend extraneous cognitive effort attending to the facial expressions of the speaker or movements of the animated agent, which may interfere with the germane load intake of the learners. Both fine design of the on-screen pedagogical agent and the modality effect (i.e., narration and visualizations rather than text and visualizations) compete for the limit capacity of cognitive load, and thus learning is not necessarily improved (R. K. Atkinson et al., 2009). In Dunsworth and Atkinson’s investigation (2007), although significance was found in answering retention questions, transferred learning was not observed, which echoes the assumption of the image principle.

History of Redundancy Study in Multimedia Learning

Since multimedia learning environments can provide a variety of components to enhance learning, literature indicates the necessity to examine whether learning is enhanced when two or more components are presenting redundant information (e.g., the presented narration is merely repeating the on-screen text). According to cognitive load theory, simultaneously redundant information presented to learners may hinder learning.

Studies that have investigated combinations of redundant on-screen text, visualizations and narrations have been well-documented (Barron & Atkins, 1994; Diao & Sweller, 2007; Dowell & Shmueli, 2008; Guan, 2009; Harskamp, Mayer, & Suhre, 2007; Jamet & Le Bohec, 2007; Kalyuga, Chandler, & Sweller, 1999; Kalyuga, et al., 2004; Tsai, 2006). The primary goals of these studies were to investigate the redundant effect when the "same information" was presented redundantly to the audiences either visually or verbally. However, the findings were not always consistent. A brief highlight of redundancy studies are described in the following review.

Harskamp and his colleagues (2007) found that a graphics-narration group outperformed a graphics-text group on a transfer test. They required Dutch secondary students to record time spent when they went through a self-paced multimedia lesson on animal behavior. Participants in the graphics-narration group recorded less time spent and had better scores on the transfer test than the graphics-text alone group. With this observation, the authors suggested that multimedia lessons may increase learning comprehension by including spoken information rather than printed text. In addition, a spoken multimedia lesson may require less time for the learners to assimilate the information.

Mayer conducted a series of experiments studying the effects of redundancy in multimedia learning. He then concluded the *redundancy principle* and suggested that students learn better from concurrent visualization and narration rather than from concurrent visualization, narration, and text (Mayer, 2009). In his investigation, he found that students who took the lesson along with visual-narration performed better than students who took the lesson along with visual-narration-text (i.e., the script of narration).

The “attrition” of students’ cognitive load was found when students simultaneously watched the graphics, read the on-screen-text, and listened to the narration.

Tsai (2006) conducted a study investigating the redundant effects on ice hockey referees’ training through a multimedia interface with various feedback modes: video, text, and audio. The video-text-audio group outperformed video-text and video-audio groups on a recall evaluation test. In addition, a higher level of confidence regarding the correctness of answers was presented among the participants in the video-text-audio group. A negative effect of redundancy was not found which indicates that redundancy is beneficial in learning.

A redundant experiment was also conducted in the simulation of medical patient monitoring. Seagull and his colleagues (2001) designed a redundant study where participants were required to perform a manual compensatory tracking task by operating a joystick. In the mean time, they needed to monitor a simulated patient aurally, visually, and both aurally and visually at the same time using six vital signs which were displayed through a simulated monitoring system. When any of the six vital signs displayed (i.e., visually, aurally, or concurrently) were of abnormal value, participants were required to perform a detection task. Insignificantly less time spent on the detecting task was found in the concurrent and the visual group, which was a possible benefit of the redundancy effect. However, the redundant group performed lower than the other two groups in the tracking task, whereas the audio group was the least distracted in tracking performance of the three groups. A negative redundant effect was observed in this study.

Diao and Sweller (2007) conducted a redundancy study in language learning where they examined students’ lexical abilities and the level of text comprehension in two-group settings: written and spoken text presentation, and written presentation only. The redundant group underperformed in both the comprehensive level and the lexical level to the written only presentation group. A negative redundant effect was observed.

Kalyuga and his colleagues (1999) conducted a redundancy study for learning fusion diagrams with three group settings: visual and audio text (i.e., the redundant group), visual text only, and audio text only. The audio text group outperformed both the visual text only and the redundant group on an achievement test. The audio text group also reported a generally lower level of mental effort in a self-rating survey. So in this study, negative redundant effect was observed. Similar effects were identified in later study (Leahy, et al., 2003); however, the authors reported when the visuals and audio represented highly interrelated content which were less likely to be understood in isolation, better performance was found in the redundant group.

Craig and his colleagues (2002) conducted a redundant study where they incorporated an animated pedagogical agent on the computer screen with two experiments. The first experiment examined the agent property in comparison to static graphics, sudden onset (i.e., illuminate each elements in the static graphic by changing bright colors), and animation. The second experiment applied printed words, spoken words, and redundant words with the on screen pedagogical agent. The result again showed the negative effect of the redundancy effect where the spoken words group outperformed both the redundant and the printed words group.

Houts and his colleagues (2006) conducted a study on how visual and audio text could help communicate health education through pictures. The addition of redundancy design positively helped learners with limited reading skills. The authors pointed out that lower reading skilled learners might “bypass” the text and try to understand and interpret meanings of instructional visual materials just by guessing. In this case, the spoken information promoted understanding, and a positive redundancy effect was observed.

Visual and audio information should not be separated (Mayer & Anderson, 1992; Mayer & Sims, 1994). According to Mayer and his colleagues, visual and audio materials improve learning only when they are presented concurrently. This suggestion echoes the temporal and spatial contiguity effect (Mayer, 2009). According to Mayer, if the redundant information is more than just repeating the presentation (i.e., explaining a visualization with printed words and/or spoken text at one time), a concurrent design is appropriate. In a supporting study, Leahy and his colleagues (2003) explained that under such conditions, the materials cannot be understood in isolation. Learners need more resources before they can comprehend the information. Therefore, it can be conjectured that higher element interactivity materials or more complex content may be appropriately designed in a redundant format for enhancing learning. There are, however, some caveats.

Certain materials should be presented simultaneously whereas others should not. Within the inseparable context, learners are paying attention to different modalities at the same time (i.e., visualizations and audios) where an effect of *split-attention* may occur (Kalyuga, et al., 1998, 1999, 2004). According to Kalyuga and his colleagues (2004), redundant materials “merely re-describe the other resource in a different form or mode” (p. 578). Redundancy provides no more knowledge for the learners but requires extra mental effort. Therefore, they suggest a non-concurrent presentation. They state that

> “…such redundant information might be to present the visual text only after the auditory explanation has been fully articulated, not simultaneously with an auditory narration of the text…visual and auditory explanations need not be mentally integrated in working

> memory and thus do not compete for working memory resources.” (p. 570)

Non-concurrent presentation of redundant visual text and audio was found to be more effective than concurrent presentation in technical apprentice training. In their observations, when visual text and audio instruction was applied to students one after another rather than concurrently, better performance was observed. They further suggested that when the concurrent text contained a large amount of information, presenting small segments excerpted from the concurrent text could be the next step in redundancy research.

Jamet and Le Bohec (2007) contested the previous approach. They contended that the instructional format using verbal and nonverbal channels non-concurrently in accordance with the dual coding in multimedia learning, should be considered as “manipulation of repetition” rather than “redundancy”. They concluded that the performance of the learners in the study done by Kalyuga and his colleagues (2004) was found to be beneficial because the non-concurrent presentation extended the possibility of a “second chance” for the learners to “rehearse” the materials. They then took the suggestion from Kalyuga and his colleagues to investigate the “small segments” approach for redundancy research. Progressive/subsequent text presentation regarding the redundant information was examined using three groups: no-text; progressive/subsequent text; and all text presented together (i.e., redundant text). As a result, no particular benefit was found by using progressive redundancy while both the redundant groups manifested the negative effect of cognitive overload.

Concise Redundancy

Dowell and Shmueli (2008) in their redundant research suggested that a revised form of the redundant text would be the next step for redundancy investigation. Mean time, Mayer and Johnson (2008) published a study indicating a concise form of on-screen text (i.e., shortened text segments that are revised from the original speech/narration scripts) along with graphics and speech as the instructional material resulted in better student performance on comprehension accuracy and shorter response time.

Students in the revised redundant group outperformed both the graphics/speech only group and the graphics/speech/redundant (i.e., original text) group on these tests. The researchers' finding indicated that when designing multimedia instructional materials, in addition to graphics and speech, adding a revised form of redundant materials (i.e., concise redundancy), would likely help students better comprehend the presented materials.

The majority of studies that examined redundancy related topics supported Mayer's claim that students learned better from a concise redundancy than from a full-text redundancy or non-redundancy design in multimedia instruction. This present study is based on the support of this body of literature.

CHAPTER III

METHODOLOGY

The present chapter describes the components and the methodology of this study. It includes: (a) statement of research questions, (b) setting, (c) participants, (d) materials, (e) instrumentation, (f) procedures, and (g) data analysis processes.

Statement of Research Questions

In order to better investigate the effect of Concise Redundancy (CR), a series of research questions were proposed.

Q1 Does the type of graphic presentation (animation or series of stills) and text redundancy (full, concise, or none) have an effect on factual retention when controlling for spatial ability?

Q2 Does spatial ability (high or low) have an effect on factual retention when given a presentation utilizing one type of graphic (animation or series of stills) and one type of text redundancy (full, concise, or none)?

Q3 Does the type of graphic presentation (animation or series of stills) and text redundancy (full, concise, or none) have an effect on student level of confidence when controlling for spatial ability?

Q4 Does spatial ability (high or low) have an effect on student level of confidence when given a presentation utilizing one type of graphic (animation or series of stills) and one type of text redundancy (full, concise, or none)?

Setting

The study was conducted using subjects from educational technology online classes at a medium-sized university of about 10,000 students in the Rocky Mountain region of the United States. This university offered comprehensive degree programs in many areas including teacher licensing and graduate programs in education.

The ability to integrate educational technology (ET) into instruction is a critical skill for successful teaching. The ET courses were designed and delivered by educational technology faculty and were required courses for students in the Teacher Education Program (TEP) at this Rocky Mountain area university. The TEP program prepared students to be teachers in Special Education, Early Childhood Education, Elementary Education, Secondary Education, K-12, with content majors such as history, mathematics, physics, biology, chemistry, geography, TESL (i.e., Teaching English as a Second Language), communication, foreign language, etc. Thus, all students in the TEP program were required to take the ET courses.

The major purpose of the ET courses was to educate students, based on theoretical foundations, to integrate technology, computer applications, multimedia-enriched environments, and Internet resources into their future teaching. The ET courses focused on guiding students to become learning facilitators and covered several topics such as ethics of using the Internet and multimedia applications, pedagogical content knowledge related to technology, digital story-telling, wiki-development, integration of technology, lesson plan development, and digital equity. Upon completing the ET courses, students were expected to use appropriate ET strategies and solutions in their cadet and student teaching experiences. The underlying assumption was that they would become comfortable integrating technology into their daily teaching activities and would continue using technology throughout their careers as teachers.

Even though the instructional content used in the current study (i.e., earth and oceanographic science) was not covered in the curriculum in these undergraduate ET courses, the portion that focuses on the online learning and multimedia were the typical learning objectives in these courses. Therefore, while the instructional content of the multimedia was not taught, principles of multimedia design and online learning, which were part of the current study were two areas of focus within the curriculum.

Online classes are currently delivered to students using a learning management system, called Blackboard (BB), version 9.0. BB has been adopted by over 3,700 educational institutes in more than 60 countries. It is an interactive online learning management system provided by Blackboard Incorporated which is located in Washington, D.C. (BlackBoard, 2010). It uses a web-based server platform that allows instructors to customize course content for designing their online classes, and it allows learners to use several functions to interact with the course content, the instructors, and classmates. BB provides functions such as live chat; discussion boards; email for online communications; collaboration and activities; high compatibility for embedding multimedia content such as audio, video, animations, and Internet resources to facilitate teaching and learning. The instructors are also able to grade and post scores, set assignment due dates and times, and give examinations in a complete online environment.

In the setting of this present study, students were required to login to the BB system using an Internet-connected computer to access the class materials. The classes were based on a weekly schedule. The instructors used BB to announce weekly activities and assignments and forwarded the announcements to the students' emails to ensure a timely communication between the instructors and students. To successfully learn and interact with the instructor and other classmates, students needed to complete all of the assigned readings, projects, discussion board activities, group or individual activities, and other assignments within a designated time frame.

The multimedia learning activity for the present study was included as a part of the learning activities in the online classes. All of the instructional materials and instruments including the survey, multimedia videos, and test were delivered using Blackboard.

The online setting used for this study ensured that participants received consistency in instructional materials, test questions and surveys, which also helped establish reliability for the present study.

Participants

Students who enrolled in the educational technology (ET) undergraduate courses at the aforementioned Rocky Mountain region university had the opportunity to volunteer as subjects for this study. There was a sequence of two one-credit classes that all pre-service teachers were required to complete. The first class introduced them to various technologies used in teaching; the second class focused on pedagogical content knowledge related to educational technology. Both courses were taught entirely online. The two courses were required by the Teacher Education Program (TEP) at the university. Students enroll in either the elementary or secondary versions of the courses based on their licensure program.

Students who were enrolled in the TEP program were required to maintain a GPA of 2.5 or higher depending on the specific requirements of different licensure programs. Students were relatively high achievers in their academic performance with an average GPA of 3.36 (Cheng, 2006). According to a previous demographic survey of 408 TEP students at this university (Gallagher, 2003), students were mostly female (75%), Caucasian (86%), 18~25 years old (82%), and single (69%). 39% of the TEP students sought secondary licensure, and 44% sought elementary licensure. Individual advisors were assigned to each student in order to oversee and assess their progress, to determine if students met specific program standards, and to assess whether they were eligible to continue in the program.

A sample size of twenty for each group was suggested in the literature review (Ary, et al., 2002; Fraenkel & Wallen, 2000). The present study had 22~26 subjects in each of the treatment groups.

Materials

Seven videos from a National Aeronautics and Space Administration (NASA) educational animation series demonstrating oceanographic and earth science were used for the multimedia materials in the present study. These videos were: Melting Ice, Rising Sea; Salt of the Earth; The Ocean's Green Machine; The Change of the Season; In the Zone (Dead Zone in the Ocean); Water Water Everywhere. All seven videos were presented to the learners sequentially, lasting approximately 27 minutes.

For the purpose of loading subjects' working memory in preparation for the retention test, and to simulate a more authentic setting, the last video (i.e., Water Water

Everywhere) was used as an extraneous video. The information from this extraneous video was not used to develop questions in the retention test.

Six versions of each video were created by varying the text and graphic types (i.e., full on-screen text, concise on-screen text, or no on-screen text; each with animations or a series of still-images).These different versions are described below:

Series of Still Images – Voice Narration – Concise Redundancy (SVC)

The SVC multimedia video included a series of still-images that were captured from the original video. In addition, SVC utilized a concise redundancy (CR). As this title implies, CR provides a concise form of the full script in a text format on the screen. Therefore, while subjects heard a narrator reading the entire script, the text that was displayed on the screen was a shortened, concise form of that script. In this version, the series of still-images, narration, and a concise form of the text were presented concurrently.

Series of Still Images – Voice Narration – Full Text (SVF)

In the SVF multimedia video, the content was identical to the previous version (i.e., SVC) with one important exception: Students saw the full text of the narration as concurrent subtitles rather than the concise form. In this version, the series of still-images, narration, and full on-screen text were presented concurrently.

Series of Still Images – Voice Narration – No Text (SVN)

In the SVN multimedia video, elements remained the same as in the previous version (i.e., SVF) except there was no on-screen text. Only a series of still-images and narration were presented concurrently.

Animation – Voice Narration –
Concise Redundancy (AVC)

The AVC multimedia video applied CR and used animations instead of still-images. In this version, the on-screen concise redundant text (CR) was presented concurrently with narration and animation.

Animation – Voice Narration –
Full Text (AVF)

In the AVF multimedia video, elements remained the same as the previous version (i.e., AVC) except full-text subtitles of the narration were used to replace the CR text. In this version, animation, narration, and full text were presented concurrently.

Animation – Voice Narration –
No Text (AVN)

In the AVN multimedia video, elements remained the same in the previous version (i.e., AVF) except there was no on-screen text. Only animation and narration were presented concurrently.

In order to establish content validity, all of the instructional content including animations, images, narrations, and text were retrieved from the National Aeronautics and Space Administration (NASA) website and reviewed by a licensed scientific educator.

The sample screen captures from each of the six video types are included in Appendix A.

Instrumentation

Spatial Ability Tests

Each subject completed a portion of the Factor-Referenced Cognitive Test (Ekstrom, French, & Harman, 1976). This instrument measured several cognitive factors, however only the spatial ability measures were used in this study. Two specific sections of the instrument measured spatial ability: the Card-Rotation Test (which includes 20 items) and the Cube-Comparison Test (which includes 42 items). The protocol allowed subjects six minutes to complete the first section and six minutes to complete the second section. The spatial ability test took participants approximately fifteen to twenty minutes to complete including reading the instruction of the two tests.

These tests are included in Appendix B.

Retention Test

The retention test included a total of 36 questions with multiple-choice and true-false responses. The questions covered factual level content from the narration supported by the videos or series of still images. Participants had 15 minutes to answer all the questions. An example item was:

> Water regulates climates by storing ____ during the day and releasing it during the night.
>
> a. Heat
> b. Water vapor
> c. Clouds
> d. Rain

The retention questions were reviewed by a science teacher for correctness, and a question development expert for consistency and difficulty. Three graduate-level students at the university read and answered the retention tests to determine that they were clear and could be understood.

The test is included in Appendix C.

Level of Confidence

The instrument for measuring participants' level of confidence was an established motivational survey derived from Keller's (2010) ARCS model. In its original form (i.e., the Instructional Material Motivational Scale or IMMS), a total of 36 survey questions are proposed to measure learners' attention, relevance, confidence, and satisfaction toward instructional materials. According to Keller (2010), each of the four subscales can be used independently without impacting their validity and reliability. Therefore, to measure participants' level of confidence, the present study adopted the subscale of confidence which included nine items from the IMMS. Example questions were:

- When I first looked at this lesson, I had the impression that it would be easy for me;
- This material was more difficult to understand than I would like for it to be;
- After receiving the introductory information, I felt confident that I knew what I was supposed to learn from this lesson, etc.

Questions were answered using a Likert-type Scale with five levels of response: not true, slightly true, moderately true, mostly true, and very true.

IMMS has established validity and reliability through wide use by educational researchers. The author of this instrument reported a reliability of .90 using Cronbach's Alpha.

The survey is included in Appendix D.

Discussion Board

The researcher collected data from a discussion board that was created to go along with the study. The topics of the discussion came from the questionnaire for measuring student level of confidence which is described previously. Students were allowed to start new threads or respond to other students' threads. Because this data were viewed as a secondary source of data, it was not coded or organized into themes. Since it is not coded, this data source is not described in the results. However, selected individual comments from the discussion board were used as anecdotal data in the discussion to offer further explanation to results generated from the quantitative analysis. The initial discussion board text and thread topics are included in Appendix E.

Procedures

The participants (n = 153) were randomly assigned by the Learning Management System (i.e., Blackboard) to six treatment groups. Each group was assigned one of the video treatments. In Blackboard, a web link that led to the multimedia activities was provided. Once participants entered the activity website, an invitation briefly explained the nature of this study and invited student to participate. Following the invitation page (see Appendix F) was the consent form for participation (see Appendix G).

Participants were asked their gender. They then completed the spatial ability test which included the Card Rotation Test (CRT) and the Cube Comparison Test (CCT). These took approximately 18 minutes.

Following the spatial ability test, subjects then watched the treatment videos. The videos could not be pause or replayed. These took approximately 27 minutes.

Participants then completed the retention test. There were 36 items in the test and this took approximately 15 minutes.

Nine questions for measuring participants' confidence toward the multimedia lesson were then competed. These took approximately 5 minutes.

A class discussion board was developed in order to collect anecdotal data related to students' levels of confidence in learning from the multimedia lessons. This was made available one week after the other data collection.

Data Analysis

Variables

The first independent variable was the treatment which included six levels: AVC (Animation-Voice Narration-CR); AVN (Animation-Voice Narration-No text); AVF (Animation-Voice Narration-Full text); SVC (Still Images-Voice Narration-CR); SVN (Still Images-Voice Narration-No text); SVF (Still images-Voice Narration-Full text).

Gender was a second independent variable. The variable of gender was eventually excluded because of insufficient numbers of men (e.g., there was only one man in the SVF treatment compared to 21 women, and two men in the SVN treatment compared to 20 women).

The scores from the spatial ability test were used as a covariate.

The dependent variables were retention and level of confidence (LOC).

Statistical Procedures

Originally, 153 students were enrolled in the classes. A total of 11 either chose not to participate or withdrew during the study. The final number of participants was 142.

A one-way ANCOVA was used to determine the effects of the video treatments on retention with spatial ability as a covariate.

A t-test on the retention score was conducted within each of the six treatment groups by dividing participants into high and low spatial ability.

A one-way ANCOVA was used to determine the effects of the video treatments on level of confidence (LOC) with spatial ability as a covariate.

A t-test on student level of confidence (LOC) was conducted within each of the six treatment groups by dividing participants into high and low spatial ability.

CHAPTER IV

RESULTS

The purpose of this study was to investigate the effects of concise redundancy (CR) on students' retention and confidence while controlling for spatial ability. In addition, the effects of animation or still graphics along with CR were examined.

The results are divided into two sections: student achievement, and student level of confidence.

Student Achievement

Q1 Does the type of graphic presentation (animation or series of stills) and text redundancy (full, concise, or none) have an effect on factual retention when controlling for spatial ability?

Q2 Does spatial ability (high or low) have an effect on factual retention when given a presentation utilizing one type of graphic (animation or series of stills) and one type of text redundancy (full, concise, or none)?

The descriptive statistics for the student retention scores and the spatial ability covariate among the six treatments are listed in Table 2.

Table 2. Descriptive Statistics of Retention and Spatial Ability Scores by Treatment

Treatment	N	Covariate Mean (Std. Deviation)	Retention Mean (Std. Deviation)	Adjusted Retention Mean (Std. Error)
AVC	24	45.50 (18.69)	21.33 (5.46)	21.06 (1.01)
AVF	26	37.02 (15.89)	20.69 (5.00)	20.76 (0.96)
AVN	24	32.67 (13.11)	19.83 (5.14)	20.08 (1.01)
SVC	22	38.45 (13.94)	20.64 (4.44)	20.65 (1.04)
SVF	22	37.14 (17.49)	21.00 (4.77)	21.06 (1.04)
SVN	24	41.21 (16.82)	20.46 (4.44)	20.36 (1.00)
Total	142	38.67 (16.32)	20.65 (4.83)	20.66 (0.41)

Note. A = Animation, S = Series of Still Images, V = Voice Narration, C = Concise Redundancy, F = Full Text, N = No Text.

A one-way ANCOVA was conducted to investigate the relationships among the independent variable (video treatments), dependent variable (retention), and the covariate (spatial ability). The alpha level was set at .10.

In preparation for performing the ANCOVA, an examination of the assumptions of independence, normality, equality of variances, and homogeneity of regression is required. First, the independence of data were potentially threatened by the educational setting itself. The participants were all drawn from one pre-service teacher program. Thus, previous contacts might undermine the assumption of independence. However, an online setting with random group assignment was used. Second, normality was assessed with the Shapiro-Wilk test. The test confirmed the assumption of normality, $p = .056$. Third, equality of variances was assessed using Levene's Test, *F* (5, 136) = .595, *p* = .703. The test confirmed the assumption of equal variances. Finally, the assumption of homogeneity of regression was confirmed, *F* (5, 141) = .924, *p* = .468. After examining the assumptions, the ANCOVA could be conducted without modification.

Among the treatment groups, there were no significant differences found, *F* (5, 135) = .148, *p* = .980 (See Table 3). The type of graphic presentation and text redundancy did not appear to have an effect on factual retention when controlling for spatial ability.

Table 3. ANCOVA Summary Table

Source	*SS*	*DF*	*MS*	*F*	*p*
Spatial Ability	58.469	1	58.469	2.463	.119
Treatment	17.608	5	3.522	.148	.980
Error	3204.786	135	23.739		
Total	3294.092	141			

Originally, all the participants were to be split into high and low spatial ability for a treatment by spatial ability analysis. However, that procedure produced greatly unequal cell sizes and could not be conducted. As an alternative, participants in each treatment were split into high and low spatial ability using each treatment's median score. Although this limits comparisons from treatment to treatment, it does provide information on spatial ability within each one. The t-test comparisons for each of the six treatments are described below. To control for inflation of error rate, the t-tests were each conducted with an alpha of .05.

For the AVC (Animation – Voice Narration – Concise Redundancy) group, higher spatial ability (HSA) participants' scores were scores of 47 and above (n = 12). Lower spatial ability (LSA) participants' scores were scores of 41 and below (n = 12). For HSA participants, the average retention score was 22.67 (SD = 6.32). For LSA participants, the average retention score was 20.00 (SD = 4.31).

The overall examination of assumptions of independence and normality of the retention score were described previously. They were assumed as tenable. The assumption of equality of variances was confirmed using Levene's Test, $F = 2.325$, $p = .142$. After examining the assumptions, the t-test could be conducted without modification.

There was no significant difference between HSA and LSA participants on retention in the AVC treatment, $t(22) = -1.209$, $p = .240$.

For the AVF (Animation – Voice Narration –Full Text) group, higher spatial ability (HSA) participants' scores were scores of 37 and above (n = 12). Lower spatial ability (LSA) participants' scores were scores of 34 and below (n = 14). For HSA participants, the average retention score was 21.83 (SD = 4.35). For LSA participants, the average retention score was 19.71 (SD = 5.47).

The overall examination of assumptions of independence and normality of the retention score were described previously. They were assumed as tenable. The assumption of equality of variances was confirmed using Levene's Test, F .156, $p = .696$. After examining the assumptions, the t-test could be conducted without modification.

There was no significant difference between HSA and LSA participants on retention in the AVF treatment, $t(24) = -1.080$, $p = .291$.

For the AVN (Animation – Voice Narration – No Text) group, higher spatial ability (HSA) participants' scores were scores of 35 and above (n = 11). Lower spatial ability (LSA) participants' scores were scores of 33 and below (n = 13). For HSA participants, the average retention score was 20.15 (SD = 5.23). For LSA participants, the average retention score was 19.45 (SD = 5.20).

The overall examination of assumptions of independence and normality of the retention score were described previously. They were assumed as tenable. The assumption of equality of variances was confirmed using Levene's Test, $F = .319$, $p = .578$. After examining the assumptions, the t-test could be conducted without modification.

There was no significant difference between HSA and LSA participants on retention in the AVN treatment, $t(22) = .326$, $p = .748$.

For the SVC (Series of Still Images – Voice Narration – Concise Redundancy) group, higher spatial ability (HSA) participants' scores were scores of 41 and above (n = 11). Lower spatial ability (LSA) participants' scores were scores of 39 and below (n = 11). For HSA participants, the average retention score was 20.45 (SD = 3.62). For LSA participants, the average retention score was 20.82 (SD = 5.31).

The overall examination of assumptions of independence and normality of the retention score were described previously. They were assumed as tenable. The assumption of equality of variances was confirmed using Levene's Test, $F = 2.427$, $p = .135$. After examining the assumptions, the t-test could be conducted without modification.

There was no significant difference between HSA and LSA participants on retention in the SVC treatment, t(20) = .188, p = .853.

For the SVF (Series of Still Images – Voice Narration – Full Text) group, higher spatial ability (HSA) participants' scores were scores of 38 and above (n = 11). Lower spatial ability (LSA) participants' scores were scores of 36 and below (n = 11). For HSA participants, the average retention score was 21.27 (SD = 3.93). For LSA participants, the average retention score was 20.73 (SD = 5.68).

The overall examination of assumptions of independence and normality of the retention score were described previously. They were assumed as tenable. The assumption of equality of variances was confirmed using Levene's Test, $F = 4.312$, $p = .051$. After examining the assumptions, the t-test could be conducted without modification.

There was no significant difference between HSA and LSA participants on retention in the SVF treatment, t(20) = -.262, p = .796.

For the SVN (Series of Still Images – Voice Narration – No Text) group, higher spatial ability (HSA) participants' scores were scores of 44 and above (n = 12). Lower spatial ability (LSA) participants' scores were scores of 43 and below (n = 12). For HSA participants, the average retention score was 19.58 (SD = 3.53). For LSA participants, the average retention score was 21.33 (SD = 5.21).

The overall examination of assumptions of independence and normality of the retention score were described previously. They were assumed as tenable. The assumption of equality of variances was confirmed using Levene's Test, $F = .993$, p

= .330. After examining the assumptions, the t-test could be conducted without modification.

There was no significant difference between HSA and LSA participants on retention in the SVN treatment, $t(22) = -.963$, $p = .346$.

None of the high and low spatial ability comparisons for the six groups were significant. Spatial ability did not appear to have an effect on factual retention for the various graphic presentations and text conditions examined.

Student Level of Confidence (LOC)

Q3 Does the type of graphic presentation (animation or series of stills) and text redundancy (full, concise, or none) have an effect on student level of confidence when controlling for spatial ability?

Q4 Does spatial ability (high or low) have an effect on student level of confidence when given a presentation utilizing one type of graphic (animation or series of stills) and one type of text redundancy (full, concise, or none)?

The descriptive statistics for student level of confidence and the spatial ability covariate among the six treatments are listed in Table 4.

Table 4. Descriptive Statistics of Student Level of Confidence (LOC) by Treatment

Treatment	N	Covariate Mean (Std. Deviation)	Mean of LOC (Std. Deviation)	Adjusted LOC Mean (Std. Error)
AVC	24	45.50 (18.69)	29.29 (6.42)	29.20 (1.38)
AVF	26	37.02 (15.89)	25.88 (7.44)	25.91 (1.30)
AVN	24	32.67 (13.11)	26.04 (6.84)	26.13 (1.38)
SVC	22	38.45 (13.94)	27.32 (7.06)	27.32 (1.42)
SVF	22	37.14 (17.49)	27.14 (5.64)	27.16 (1.42)
SVN	24	41.21 (16.82)	24.50 (6.04)	24.46 (1.36)
Total	142	38.67 (16.32)	26.67 (6.67)	26.70 (0.56)

Note. A = Animation, S = Series of Still Images, V = Voice Narration, C = Concise Redundancy, F = Full Text, N = No Text.

A one-way ANCOVA was conducted to investigate the relationships among the independent variable (video treatments), dependent variable (level of confidence), and the covariate (spatial ability). The alpha level was set at .10.

In preparation for performing the ANCOVA, an examination of the assumptions of independence, normality, equality of variances, and homogeneity of regression is required. First, although the participants would have likely had prior contact, the use of random assignment of treatments reduced the possible risk regarding the assumption of independence. Second, normality was assessed with the Shapiro-Wilk test. The test confirmed the assumption of normality, $p = .647$. Third, equality of variances was assessed using Levene’s Test, $F\ (5, 136) = .766$, $p = .576$. The test confirmed the assumption of equal variances. Finally, the assumption of homogeneity of regression was confirmed, *F* (5, 141) = 1.70, *p* = .139. After examining the assumptions, the ANCOVA could be conducted without modification.

Among the treatment groups, there were no significant differences found, *F*(5, 141) = 1.371, *p* = .239 (See Table 5). The type of graphic presentation and text redundancy did not appear to have an effect on level of confidence when controlling for spatial ability.

Table 5. ANCOVA Summary Table

Source	*SS*	*DF*	*MS*	*F*	*p*
Spatial Ability	7.817	1	7.817	.177	.674
Treatment	302.387	5	60.477	1.371	.239
Error	5954.117	135	44.105		
Total	6279.444	141			

As with the retention variable, all the participants were to be split into high and low spatial ability for a treatment by spatial ability analysis of level of confidence. However, that procedure produced greatly unequal cell sizes and could not be conducted. As an alternative, participants in each treatment were split into high and low spatial ability using that treatment's median score. Although this limits comparisons from treatment to treatment, it does provide information on spatial ability within each one. The t-test comparisons for each of the six treatments are described below. To control for inflation of error rate, the t-tests were each conducted with an alpha of .05.

For the AVC (Animation – Voice Narration – Concise Redundancy) group, higher spatial ability (HSA) participants' scores were scores of 47 and above (n = 12). Lower spatial ability (LSA) participants' scores were scores of 41 and below (n = 12). For HSA participants, the average LOC was 29.58 (SD = 6.79). For LSA participants, the average LOC was 29.00 (SD = 6.31).

The overall examination of assumptions of independence and normality of the LOC were described previously. They were assumed as tenable. The assumption of equality of variances was confirmed using Levene's Test, $F = .297$, $p = .591$. After examining the assumptions, the t-test could be conducted without modification.

There was no significant difference between HSA and LSA participants on LOC in the AVC treatment, $t(22) = -.218$, $p = .829$.

For the AVF (Animation – Voice Narration – Full Text) group, higher spatial ability (HSA) participants' scores were scores of 37 and above (n = 12). Lower spatial ability (LSA) participants' scores were scores of 34 and below (n = 14). For HSA participants, the average LOC was 25.67 (SD = 8.37). For LSA participants, the average LOC was 26.67 (SD = 6.87).

The overall examination of assumptions of independence and normality of the LOC were described previously. They were assumed as tenable. The assumption of equality of variances was confirmed using Levene's Test, $F = .157$, $p = .695$. After examining the assumptions, the t-test could be conducted without modification.

There was no significant difference between HSA and LSA participants on LOC in the AVF treatment, $t(24) = .136$, $p = .893$.

For the AVN (Animation – Voice Narration – No Text) group, higher spatial ability (HSA) participants' scores were scores of 35 and above (n = 11). Lower spatial ability (LSA) participants' scores were scores of 33 and below (n = 13). For HSA participants, the average LOC was 27.73 (SD = 7.36). For LSA participants, the average LOC was 24.62 (SD = 6.31).

The overall examination of assumptions of independence and normality of the LOC were described previously. They were assumed as tenable. The assumption of equality of variances was confirmed using Levene's Test, $F = .629$, $p = .436$. After examining the assumptions, the t-test could be conducted without modification.

There was no significant difference between HSA and LSA participants on LOC in the AVN treatment, $t(22) = -1.117$, $p = .276$.

For the SVC (Series of Still Images – Voice Narration – Concise Redundancy) group, higher spatial ability (HSA) participants' scores were scores of 41 and above (n = 11). Lower spatial ability (LSA) participants' scores were scores of 39 and below (n = 11). For HSA participants, the average LOC was 23.64 (SD = 5.70). For LSA participants, the average LOC was 31.00 (SD = 6.51).

The overall examination of assumptions of independence and normality of the LOC were described previously. They were assumed as tenable. The assumption of equality of variances was confirmed using Levene's Test, $F = .103$, $p = .751$. After examining the assumptions, the t-test could be conducted without modification.

The LSA participants had significantly higher LOC than HSA participants in the SVC treatment, $t(20) = 2.823$, $p = .011$.

For the SVF (Series of Still Images – Voice Narration – Full Text) group, higher spatial ability (HSA) participants' scores were scores of 38 and above (n = 11). Lower spatial ability (LSA) participants' scores were scores of 36 and below (n = 11). For HSA participants, the average LOC was 28.91 (SD = 5.03). For LSA participants, the average LOC was 25.36 (SD = 5.89).

The overall examination of assumptions of independence and normality of the LOC were described previously. They were assumed as tenable. The assumption of equality of variances was confirmed using Levene's Test, $F = .181$, $p = .675$. After examining the assumptions, the t-test could be conducted without modification.

There was no significant difference between HSA and LSA participants on LOC in the SVF treatment, $t(20) = -1.519$, $p = .144$.

For the SVN (Series of Still Images – Voice Narration – No Text) group, higher spatial ability (HSA) participants' scores were scores of 44 and above (n = 12). Lower spatial ability (LSA) participants' scores were scores of 43 and below (n = 12). For HSA participants, the average LOC was 25.33 (SD = 6.40). For LSA participants, the average LOC was 23.67 (SD = 5.82).

The overall examination of assumptions of independence and normality of the LOC were described previously. They were assumed as tenable. The assumption of equality of variances was confirmed using Levene's Test, $F = .215$, $p = .647$. After examining the assumptions, the t-test could be conducted without modification.

There was no significant difference between HSA and LSA participants on LOC in the SVN treatment, $t(22) = -.667$, $p = .511$.

Only one of the six groups had a significant difference in level of confidence between high and low spatial ability. In the SVC (Series of Still Images – Voice Narration – Concise Redundancy) group, those designated as lower spatial ability reported higher levels of confidence than those with higher spatial ability. Spatial ability did appear to have an effect in this one case.

CHAPTER V

DISCUSSION

The purpose of this study was to investigate the effects of concise redundancy (CR) on students' retention and confidence while controlling for spatial ability. In addition, the effects of animation or still graphics along with CR were examined.

Summary of Results by Research Question

Q1 Does the type of graphic presentation (animation or series of stills) and text redundancy (full, concise, or none) have an effect on factual retention when controlling for spatial ability?

There was no significant difference found in factual retention when controlling for spatial ability. In this study, when presenting multimedia lessons with animation or a series of still graphics, the text redundancy (full, concise, or none) did not have an effect on retention.

Q2 Does spatial ability (high or low) have an effect on factual retention when given a presentation utilizing one type of graphic (animation or series of stills) and one type of text redundancy (full, concise, or none)?

There was no significant difference in factual retention found between high and low spatial ability participants in the six treatments. In this study, high or low spatial ability did not have an effect on factual retention (a) when students were given either animation or series of still graphics, or (b) when students were given any type of text redundancy (full, concise, or none).

Q3 Does the type of graphic presentation (animation or series of stills) and text redundancy (full, concise, or none) have an effect on student level of confidence when controlling for spatial ability?

There was no significant difference found on students' level of confidence when controlling for spatial ability. In this study, when presenting multimedia lessons with animation or series of still graphics, the text redundancy (full, concise, or none) did not have an effect on students' level of confidence.

Q4 Does spatial ability (high or low) have an effect on student level of confidence when given a presentation utilizing one type of graphic (animation or series of stills) and one type of text redundancy (full, concise, or none)?

Only one of the six groups had a significant difference in level of confidence between high and low spatial ability. In the SVC group (Series of Still Images – Voice Narration – Concise Redundancy, those designated as lower spatial ability learners reported higher levels of confidence than those with higher spatial ability. Spatial ability did have an effect in this one case.

Discussion of Concise Redundancy

Dowell and Shumeli (2008) suggested a shortened form of redundant text presented with instructional graphics would promote learning outcomes. Mayer and Johnson (2008) reported that a shortened form of redundancy of the on-screen text improved students' performance on comprehension accuracy and resulted in shorter response times when learning with still graphics. However, in the current study, concise redundancy did not have an effect on students' retention. According to Leahy and his collegues (2003), the need to include redundant text was to provide reinforcing information that would enhance learning when the content involved higher element interactivity (e.g., the redundant text and the content could not be understood in isolation);

and the content involved higher levels of complexity. Although complex instructional content was used, findings in the present study were not consistent with the suggestion from Leahy, et al. (2003).

The investigation of participants' level of confidence when learning with redundant text is rare in the literature. However, one such study reported a higher level of confidence in ice hockey referee training participants when comparing a video-text-audio treatment (i.e., redundant) with video-text and video-audio treatments (Tsai, 2006). No differences were found in the current study when looking at the effects of concise redundancy on level of confidence.

In the literature, results regarding text redundancy are not consistent (Barron & Atkins, 1994; Diao & Sweller, 2007; Dowell & Shmueli, 2008; Guan, 2009; Harskamp, et al., 2007; Jamet & Le Bohec, 2007; Kalyuga, et al., 1999; Kalyuga & Sweller, 2004; Tsai, 2006). The following discussion explores why concise redundancy may not have had an effect in the present study.

Chunked Form of Full-Text

Concise redundancy was not the only condition that provided unexpected results. The full-text treatments were expected to overload the participants, but they did not. Previous studies have demonstrated a negative effect of full-text redundancy (Diao & Sweller, 2007; Kalyuga, et al., 1999, 2004; Leahy, et al., 2003).

In the present study, the full-text was presented concurrently as subtitles that followed the narration, whereas previous studies had the full-text displayed in its entirety on the computer screen. In those studies, students had to visually search and skim through the manuscript while listening to the narration and while viewing the static graphics at the same time. According to Sweller and his colleagues (1998), this setting caused the participants' working memory to be overloaded resulting in poorer learning compared with the groups that received concise redundancy. Researchers have suggested that only a limited amount of information could be viewed because of the limitations of the working memory (Cowan, 2005; Miller, 1956). Therefore, the setting overloaded participants' working memory and led to poor performance.

In the present study, narrations were reproduced as subtitles, which could be considered as a *chunked* form of the original. The redundant text was not presented in the same format as previous studies. A negative full-text redundancy effect may not have been found because the format (i.e., chunked) did not overload the participants' working memory. As a result, the full-text groups performed similarly as other treatment groups.

Time Limitations

Time was a factor that was controlled in this study. Although studies on the comparisons of timed and untimed tests (Kenworthy, 2006; Lesaux, Pearson, & Siegel, 2006; Petersen, 2009) have reported inconsistent results (i.e., students performed better in timed than untimed tests; student performed worse in timed than untimed test; and student performed similarly in timed and untimed tests), the purpose of controlling time was to simulate an authentic learning environment. Time limitations to complete class activities are common in classrooms. Also, timed quizzes are commonly used to measure learning achievement (Chang, 2010).

Timing concerns began with the measure of students' spatial ability. Students commented that "…after reading the directions and knowing that I was going to be timed, this made me extremely nervous." This was a standardized test developed by Educational

Testing Services (ETS). To ensure the quality of the measurement, participants were required to complete the tests (i.e., card rotations and cube comparisons) within a prescribed time period. Students were not allowed to take additional time, so they had to work very quickly. It appeared that the spatial ability test was a difficult cognitive task for the participants. This feeling of expediency may have been carried over to the multimedia lessons. Student commented that "…but it made me nervous that we were given a time limit"; and "…I was just frustrated about how much time was given to complete the quiz." Students may have thought that they needed to continue to work quickly through the multimedia lessons. As a result, they may have felt rushed and this could have interfered with their ability to adequately grasp the content. One student commented that"…I had just learned so much new information. I didn't have enough time to process everything before I was taking a test. I would have preferred more time before taking the test."

Participant Expectation and Behavior

Internet behavior as demonstrated by daily usage of a computer is a complex concept (Piazza & Bering, 2009). This information gathered from the anecdotal data (i.e., the discussion board) indicated that students initially thought that the learning activities would be fun and relaxed. These students were accustomed to learning online, but online activities often involve informal leaning that is related to specific interests (Suler, 2004). The participants' mindsets going into the one-hour multimedia activity may have changed once they saw how complex the learning topics were. Some of the subject matter was highly technical and very detailed, and much of it was probably not related to their areas of interest. The following anecdotal comments from five different participants explain how students' perceptions of the learning tasks changed once they engaged in the lessons.

Participant one stated, “The multimedia project was an interesting experience that did not end up as I thought it would”.

Participant two stated, “When I first started this survey I thought it would probably be pretty easy, all about my opinions or background knowledge I already had. I was definitely wrong”.

Participant three stated:

> When I first looked at the lesson, I thought it wasn't going to be too complicated just a little time consuming knowing that we had to stay online for a full 60 minutes, which I was okay with. As I started going through all the material it turned out to be a lot harder than I thought it was going to be.

Participant four stated, “When I first got the assignment I thought that it would be easy to remember the information from the video’s to get a good score on the “quiz”. I quickly found out that that was not the case”.

Participant five stated:

> Even as a 3rd year college student, I felt that the information presented was overwhelming and sometimes difficult to understand. I was constantly guessing my answers because I wasn’t completely confident that I knew what I was doing.

The students’ expectations seemed to indicate that they thought little engagement would be needed for the study. In reality, they were required to take a spatial ability test, watch several videos, and complete an achievement test. Students were mentally unprepared to engage in the complex nature of the learning activities. Even though a detailed explanation of the entire process of the study was presented at the beginning, participants probably did not read the instructions carefully. This could be related to typical Internet browsing behavior in which students engage on a daily basis.

Discussion of Graphic Presentation: Animation versus Series of Still Pictures

In the present study, students in the animated and static graphic groups did not perform differently on the retention test in all conditions (i.e., concise redundancy, full, and no text). This result is congruent with the views of Tversky, Morrison, & Betrancourt (2002). They argued that the level of complexity of the animation should be taken into account when analyzing its potential effectiveness on learning. They stated that animations that are overly complex are ineffective. The animations used in the current study contained very detailed information and were complex. In this situation, concise redundancy was used with the purpose of reinforcing retention by loading participants' verbal channel (Paivio, 1971). However, the complexity of the graphics may have overshadowed the benefits of the redundant text. As a result, none of the groups showed significant differences on the retention test.

In addition to the complexity of the content, all of the information was presented only once (i.e., non-self-paced learning). Participants watched 27 minutes of relatively complex video-based animations. The video materials demonstrated earth and oceanographic science with which most of the students were not previously familiar (e.g., how the salinity of the ocean affects the climate of the earth). Students seemed unable to learn the content well after a single viewing of the multimedia lessons.

Not being able to stop or replay the video-based instruction likely affected both animation and still image groups. Several students commented that they would have done better if they were given the option to replay the videos. The following comments were posted by four different participants in the discussion board.

Participant one stated:

> …I think it would have been smart of me to take some notes. It is also complicated because you only have so much time to watch the videos so it isn't like I could stop and write down things from the videos.
>
> Participant two stated, "… I would have done better if I had more options to listen to the videos again".
>
> Participant three stated, "…I think we should have been able to stop and rewind them if we needed clarification".
>
> Participant four stated, "… It would have shown better results if we were allowed to stop at any times and to go back to where we left off".

Although learner control is perceived as being a positive attribute of multimedia learning, this is not always the case. One study showed that, even though students were given learner control of instructional videos, only one out of 18 participants took advantage of this opportunity (Hasler, Kersten, & Sweller, 2007). Another study observed that there were no differences between system-controlled and learner-controlled instructional videos in terms of student achievement (Tabbers, Martens, & van Merriënboer, 2004). Hicken, Sulivan, & Klein's study (1992) found that participants in the LeanPlus treatment – students who learned with less material but had the option to add more instruction – and in the FullMinus treatment – students had the full instructional content but had the option to bypass some parts – exhibited similar behaviors. Taking this information into consideration, in this present study, it is unclear whether learner control would have had an effect on achievement on the post treatment retention test. Most educational technologists would agree that allowing students to control the pace of the instruction is a major attribute of multimedia instruction especially in an online and self-paced learning environment (Gerjets, Scheiter, Opfermann, Hesse, & Eysink, 2009; Whipp & Chiarelli, 2004).

The design of the present study purposefully overloaded the participants' working memory (i.e., cognitive overload). It was necessary to overload their working memory in order to examine the differences between animated and still graphics. The reason for doing this was because a low cognitive load would have resulted in a ceiling effect. This feature clearly differentiates the current study from previous studies done by Mayer (2010).

Overall, no differences were found in the current study when looking at the effects of animation versus stills on level of confidence. When comparing groups that had animated and still graphics with either no, full or concise text, the participants exhibited similarly on the levels of confidence. Again, the fact that the instruction was complex may have contributed to this result.

Discussion of Spatial Ability

High and low spatial ability participants performed similarly on the retention test in each of the six video treatments. This finding was not consistent with the literature. Höffler (2010) reports that students with low spatial abilities assigned to static graphic treatments performed better on the retention tests than those assigned to animation groups. Researchers have also found that computer multimedia lessons promote greater learning improvement among low spatial ability learners than among high spatial ability learners (Lee, 2007).

In the current study, spatial ability was used as a measure of participants' cognitive abilities. Spatial ability is only one measure of visual literacy. There are other measures (e.g., different colors, fonts, shapes, etc.) that may also be involved in learning with multimedia instruction. These measures were not used in the current study.

Additionally, spatial ability may be either innate or learned. For example, earth science students are trained to read topographic maps. These students would be expected to perform better when learning with three-dimensional multimedia graphics (Pauli, et al., 2003). However, the present study did not find any significant differences among the participants.

Among the six video types, low and high spatial ability participants exhibited similar levels of confidence in the five treatment groups (e.g., AVC, AVF, AVN, SVF, SVN). With the narrated animated graphics, low and high spatial ability learners revealed similar levels of confidence within all conditions of text redundancy. With the static graphics, low and high spatial ability participants revealed similar levels of confidence within the conditions of full-text and no text.

When participants were given narration along with a series of static graphics and concise redundancy, low spatial ability learners exhibited significantly higher levels of confidence than high spatial ability learners. This is the only condition under which this phenomenon occurred. In a static graphic environment, low spatial ability students are not required to focus their attention on complex animations. They might have felt that they were not in the “safe zone” when the given presentation was not in static graphics. There are supports in the literature for this explanation (Höffler, 2010; Huk, 2006; Lee, 2007).

Recommendations for Future Research

Concise Redundancy

In the current study, it appears that the complexity of the materials may have contributed to the finding that resulted in no significant differences when using concise redundancy with any of the treatment groups. According to the literature, if the materials are simple, because there is less cognitive overload on the students, the inclusion of concise redundancy is not necessary in order to improve learning. However, in the current study, the materials were not simple. Their complexity may have overloaded working memory even though the researcher tried to minimize the cognitive load of the participants.

Researchers who are interested in this area may need to consider ways in which the complexity of the materials can be better controlled. They may need to experiment with different levels of complexity in order to determine what is optimal for instructional delivery of multimedia materials. Furthermore, researchers could test concise redundancy with differing levels of complexity to see where it has an effect on performance.

Animation versus Still Graphics

Along the same line with the previous suggestion, the issue of complexity of the material appears to also be important when comparing animation and still graphic presentations. Based on views from a previous study (Tversky, et al., 2002), if the material is too simple, using animation does not appear to be necessary. In this case, a series of still images would be effective and appropriate. However, if the material is highly complex, it would be difficult to compare the effects of animation with still graphics on learning outcomes.

In comparing animation with still graphics, there is probably a specific range of complexity where the animation helps convey the instructional message. Future research may consider examining methods to identify that specific range of complexity where animation could appropriately provide its advantages.

Spatial Ability

The literature has specifically reported how low spatial ability learners would have benefited more from computer multimedia lessons than high spatial ability learners. However, in the current study, it is unclear that individuals who were identified as low spatial ability learners benefitted from the multimedia lessons. Participants in the current study were all teacher preparation students who were relatively high achievers in terms of their previous GPA and academic performance. As a result, the sample used in this study was relatively homogeneous in terms of spatial ability.

For future studies that would specifically look at students' spatial ability, they would also need to consider having a better range (e.g., sample population allows a larger variety of spatial ability) to better identify individuals that would most likely benefit from such instructional materials.

Conclusion

Previous studies that concentrated on the multimedia learning effectiveness might have used materials that are relatively simplistic (e.g., refer to Mayer, 2010). The purpose of the current study was to investigate the effects of concise redundancy using animation and still graphics. Rather than create specific instructional materials, real and high quality materials from respected resources (e.g., NASA) would help instructional designers when developing high quality and authentic multimedia learning environments.

However, the complexity of the materials may have made it difficult to determine whether concise redundancy had a positive effect on learning outcomes. The actual complexity of the materials probably has as much of an effect as the conditions for concise redundancy when comparing animation to still graphics. It could be that this kind of research is highly sensitive to the issues regarding complexity. Research of this nature does require students who are subjected to high levels of cognitive load in order to compare one condition to another.

Nevertheless, the current study should provide further guidance for researchers who are interested in examining concise redundancy in animation versus still graphics. It is very important that we continue to develop more understanding in this area.

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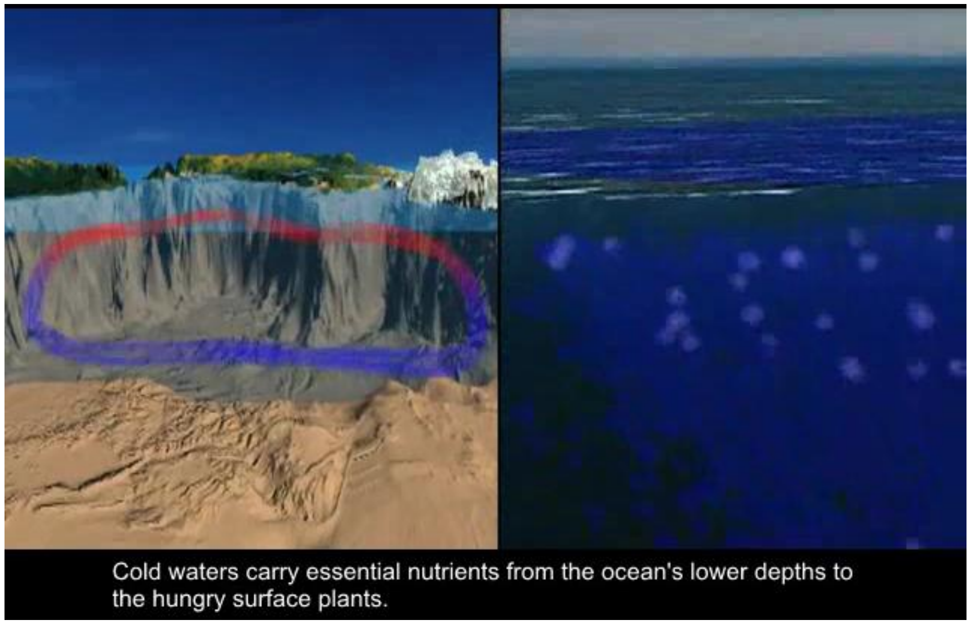
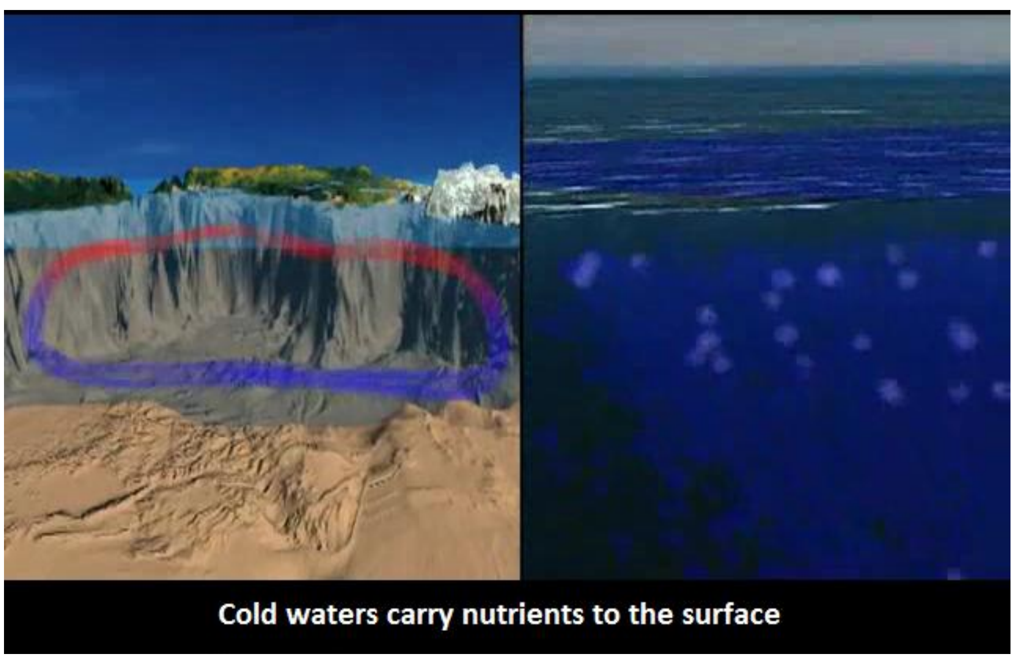
APPENDIX A

SCREEN CAPTURES OF VIDEOS

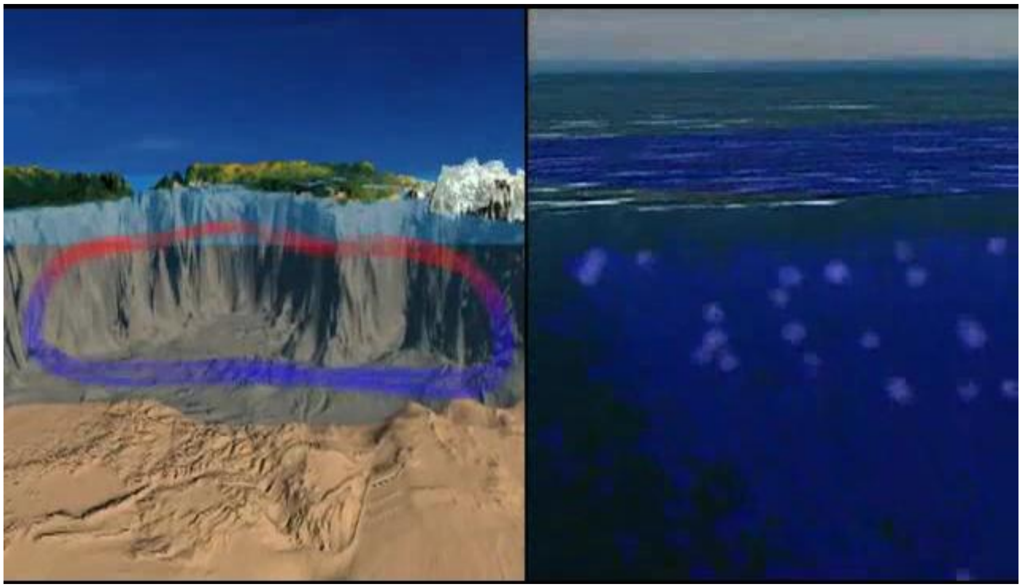
AVF & SVF



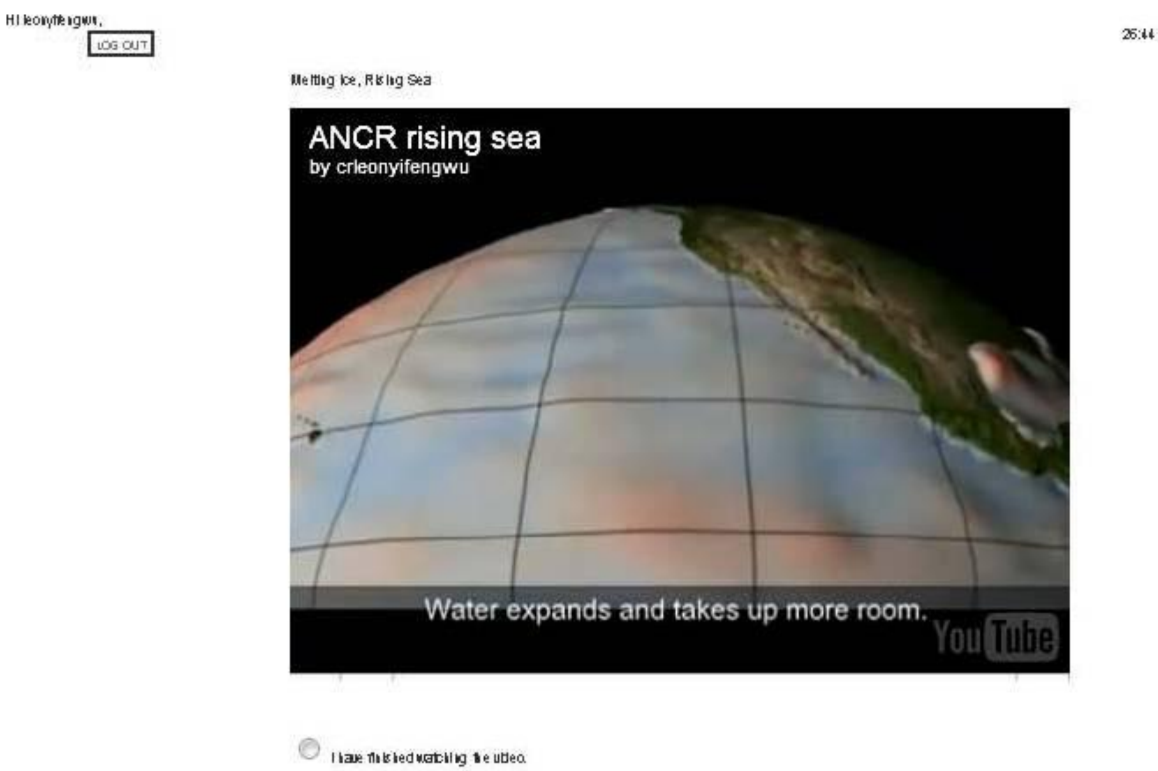
AVC & SVC



AVN&SVN



Webpage of Actual Multimedia lesson



APPENDIX B

SCREEN CAPTURES OF SPATIAL ABILITY TESTS

Card Rotation

Instruction

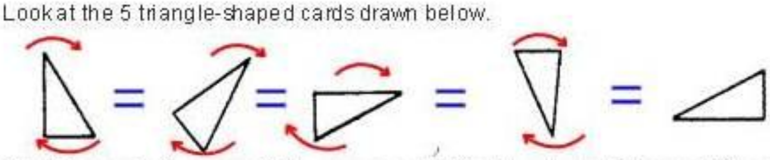
Card Rotation

Please understand that it is crucial **not to retake the test.** By doing this you will help the accuracy of the test and also the reliability of the research. Therefore, you will have only **ONE TIME ACCESS** to this test. If you close the webpage during taking the test, any data you have answered will be lost. The results of the test will NOT affect any your academic grades.

At the upright corner, you will see a timer counting from **6 minutes**. If the time is up, please still answer the question you are answering, and click the NEXT bottom. All the data you have answered before time's up will be sent (not including the last one you were answering).

This is a test of your ability to see differences in figure.

Look at the 5 triangle-shaped cards drawn below.



All of these drawings are of the same card, which has been slid around into different position on the page.

Now look at the 2 cards below.

These two cards are **not alike**. The first cannot be made to look like the second by sliding it around on the page. It would have to be **flipped over** or **made differently**.

Each problem in this test consists of one card in the question part and eight cards in the answer part. You are to decide whether each of the eight cards given in the answer part is the **same as** or **different from** the card given in the question part.

Click the box if it is the **same as** the one given in the question part.

DO NOT Click the box if it is **different from** the one given in the question part.

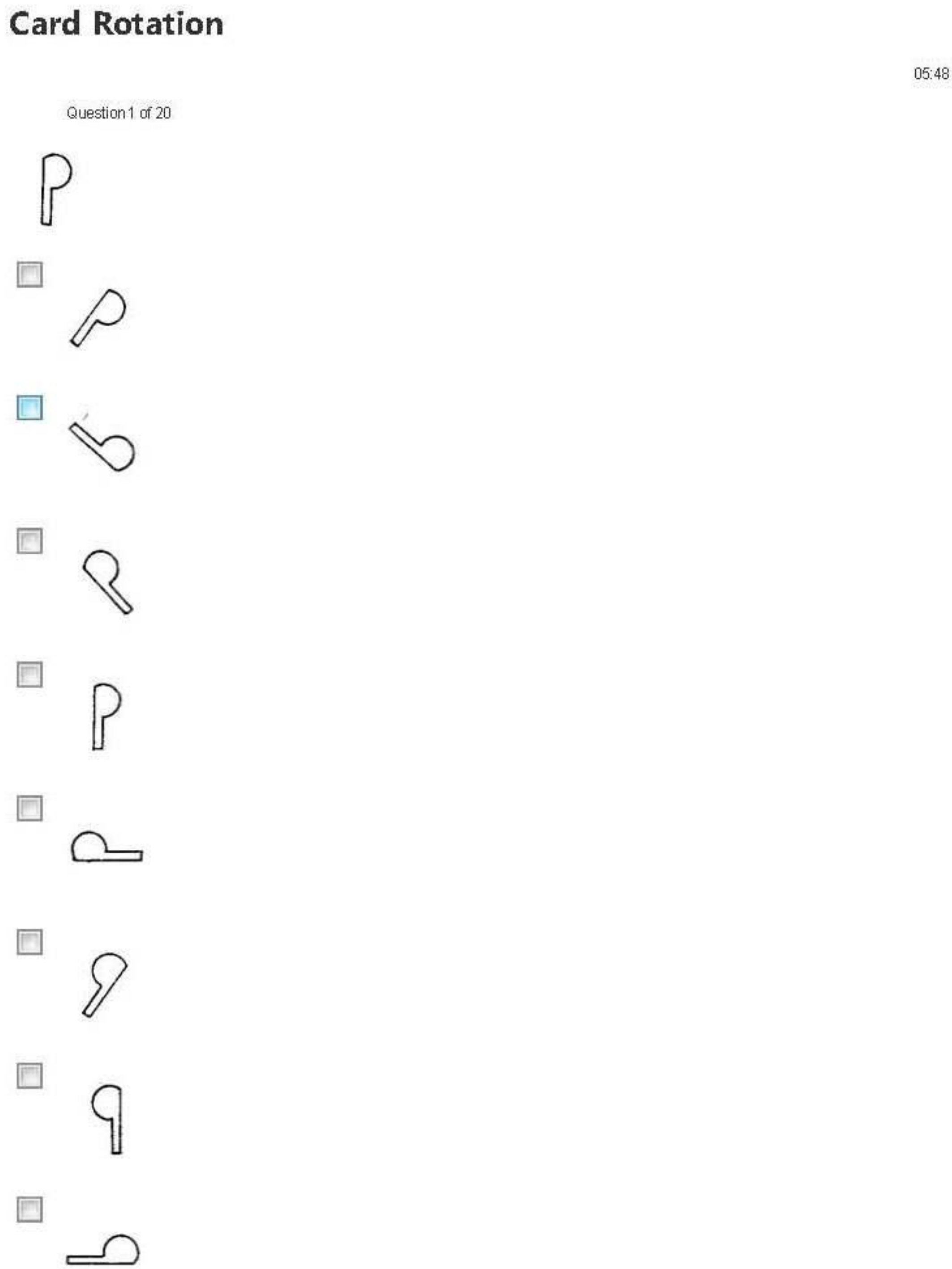
Practice on the following problem. It has been correctly answered for you.

Instruction

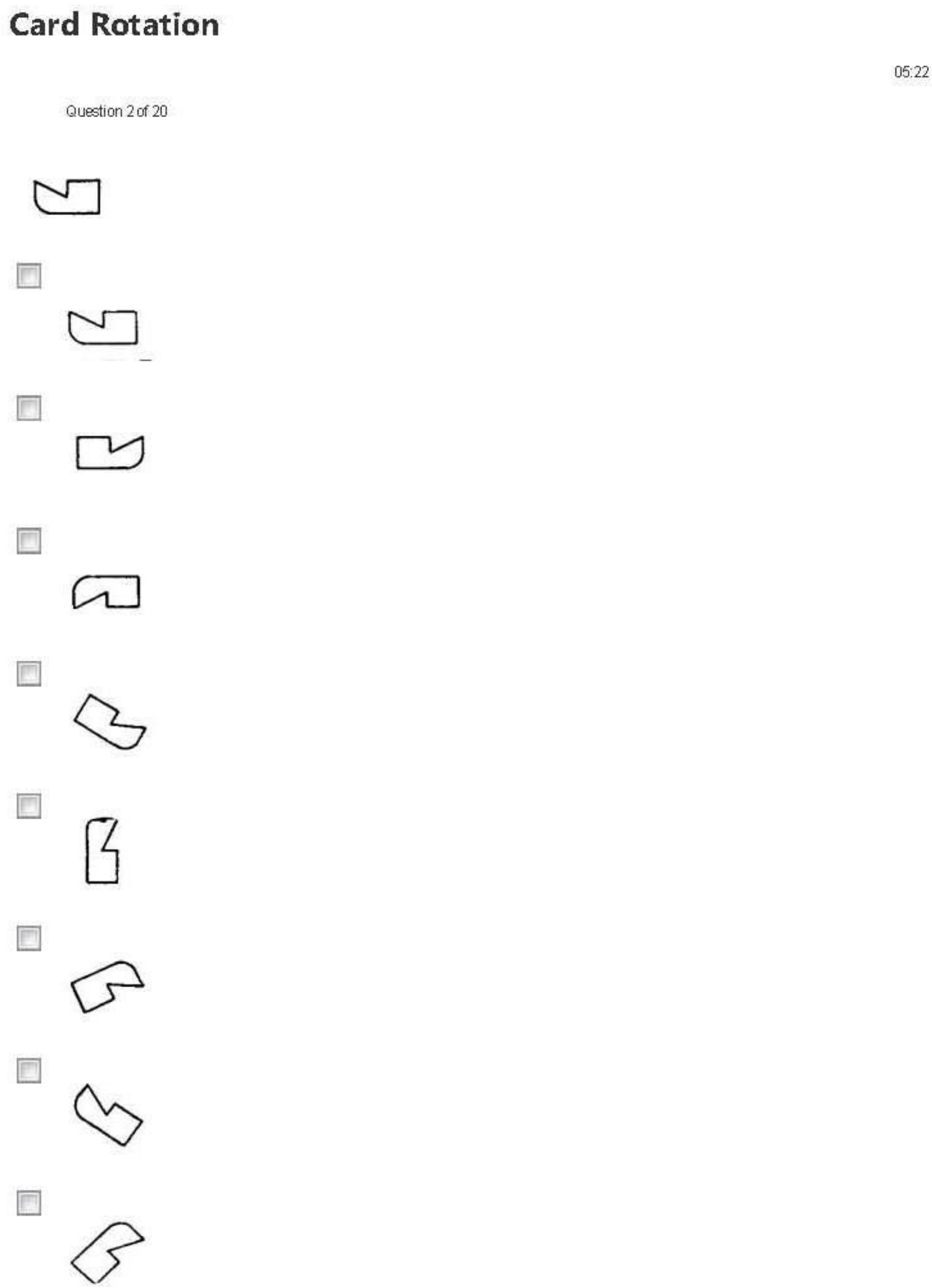
Your score on this test will be the number of items answered correctly minus the number answered incorrectly. Therefore, it will not be to your advantage to guess, unless you have some idea whether the card is the same or different. Work as quickly as you can without sacrificing accuracy.

<u>You will have 6 minutes for answering 20 rotation problems.</u>

Sample Question One



Sample Question Two



Sample Question Three

Cube Comparisons

Instruction

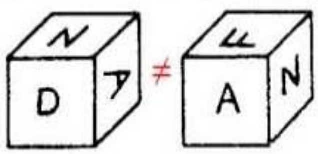
Cube Comparisons

Please understand that it is crucial **not to retake the test**. By doing this you will help the accuracy of the test and also the reliability of the research. Therefore, you will have only **ONE TIME ACCESS** to this test. If you close the webpage during taking the test, any data you have answered will be lost. The results of the test will NOT affect any your academic grades.

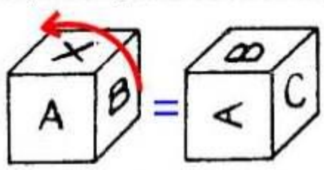
At the upright corner, you will see a timer counting from **6 minutes**. If the time is up, please still answer the question you are answering, and click the NEXT bottom. All the data you have answered before time's up will be sent (not including the last one you were answering).

Wooden blocks such as children play with are often cubical with a different letter, number, or symbol on each of the six faces (top, bottom, four sides). Each problem in this test consists of drawings of pairs of cubes or blocks of this kind. Remember, there is a different design, number, or letter on each face of a given cube or block.

Compare the two cubes in each pair below.



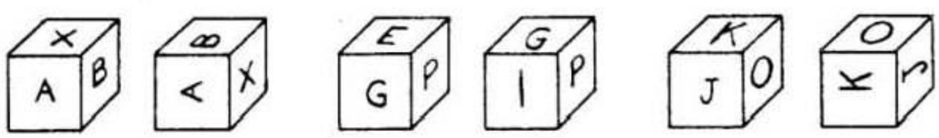
The first pair is different from each other if the left cube is turned so that the A is upright and facing you, the N would be to the left of the A and hidden, not to the right of the A as is shown on the right hand member of the pair. Thus, this pair is different from each other.



The second pair could be of the same cube because if the A is turned on its side the X becomes hidden, the B is now on top, and the C (which was hidden) now appears. Thus this pair could be of the same cube.

Note: No letter, numbers, or symbols appear on more than one face of a given cube. Except for that, any letter, number or symbol can be the hidden faces of a cube.

Work the three examples below.



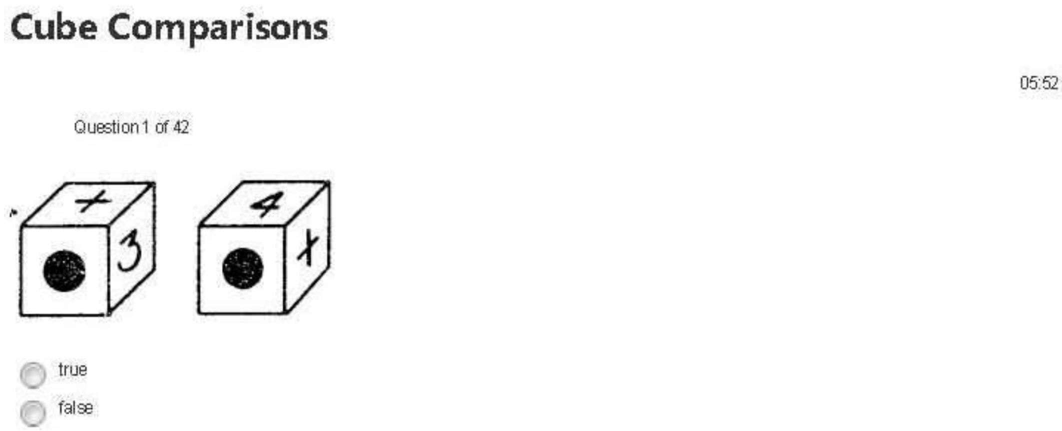
The first pair should be checked the different because the X connot be at the peak of the A on the left hand drawing and at the base of the A on the right hand drawing. The second pair is different because P has its side next to G on the left hand cube but its top next to G on the right hand cube. The blocks in the third pair are the same, the J and K are just turned on their side, moving the O to the top.

In the coming questions, please check TRUE if you feel the boxes are the same, check FALSE if you feel the boxes are different.

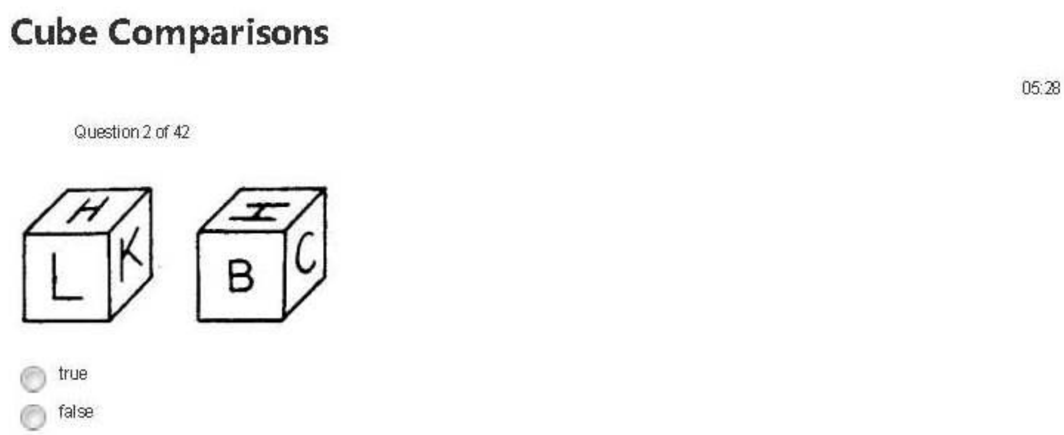
Your score on this test will be the number answered correctly minus the number answered incorrectly. Therefore, it will not be to your advantage to guess unless you have some idea which choice is correct. Work as quickly as you can without sacrificing accuracy.

You will have 6 minutes to answer 42 cube comparison problems.

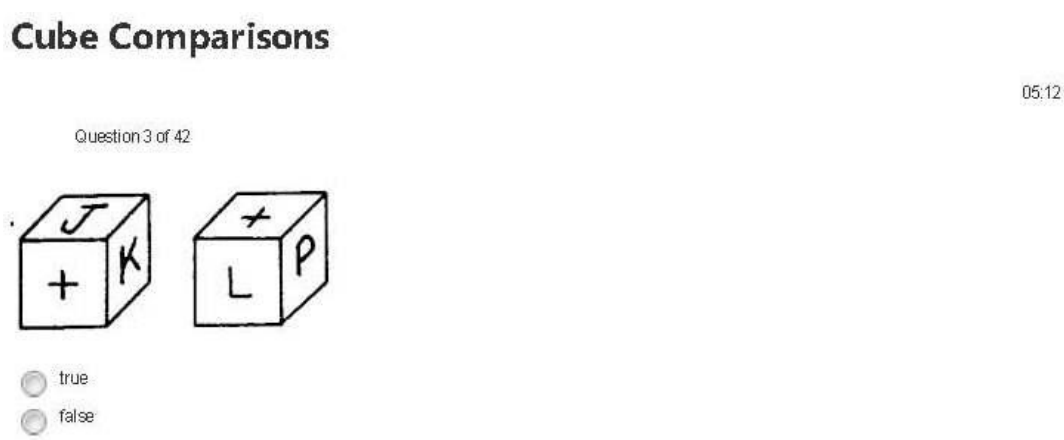
Sample Question One



Sample Question Two



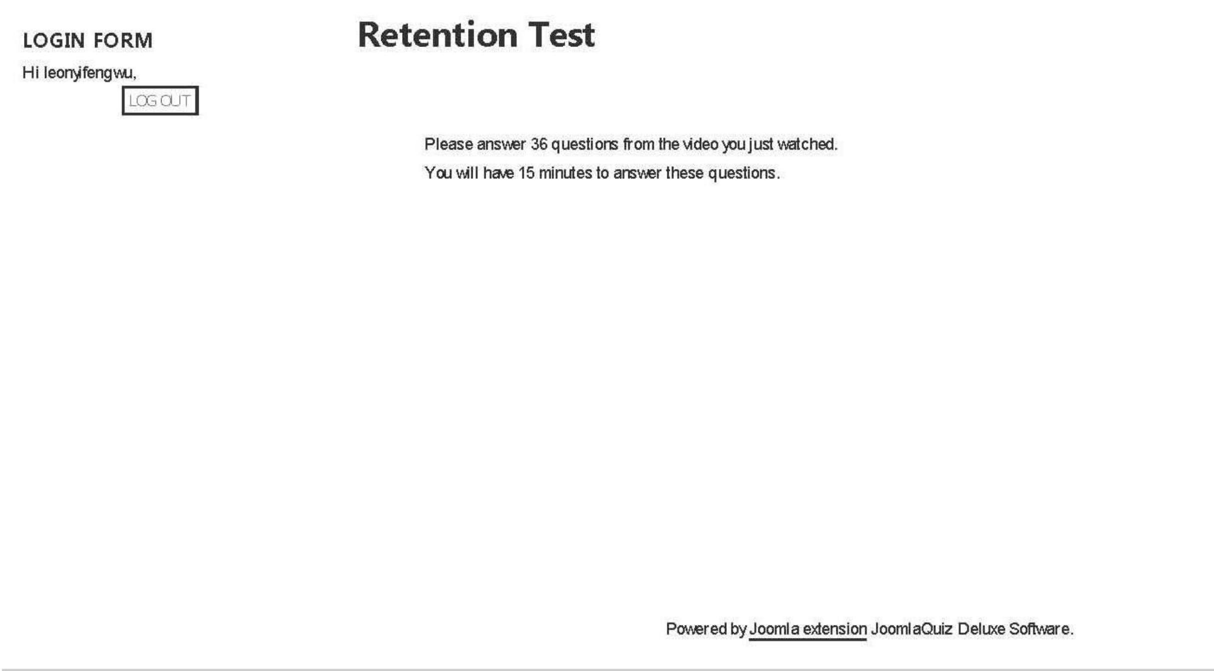
Sample Question Three



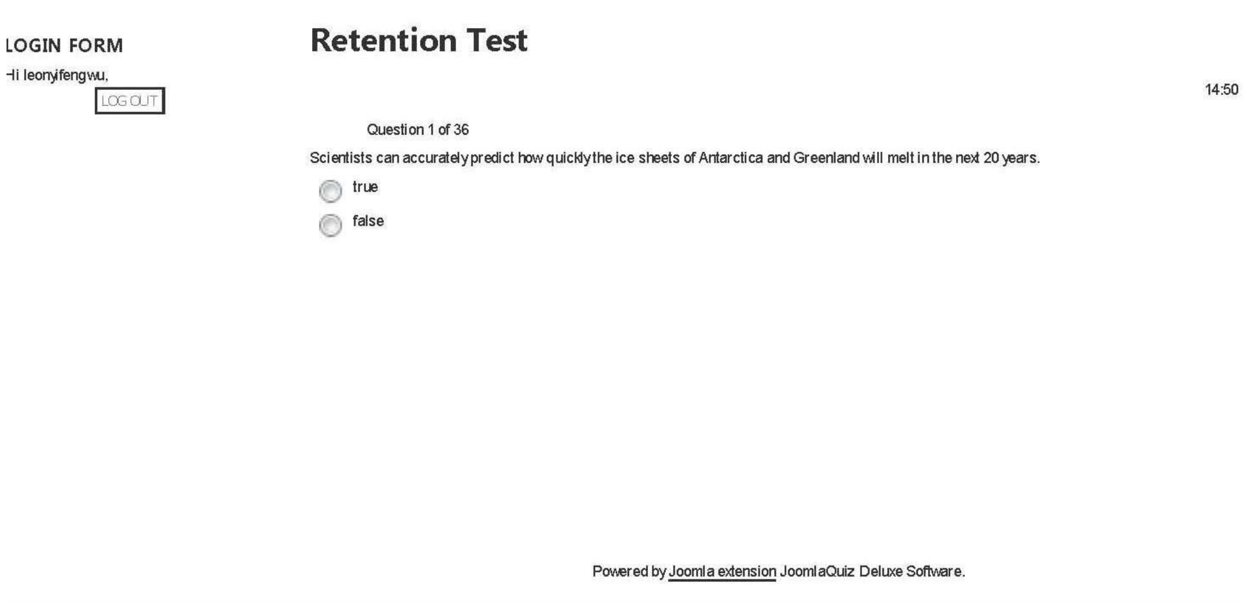
APPENDIXC

RETENTION TEST

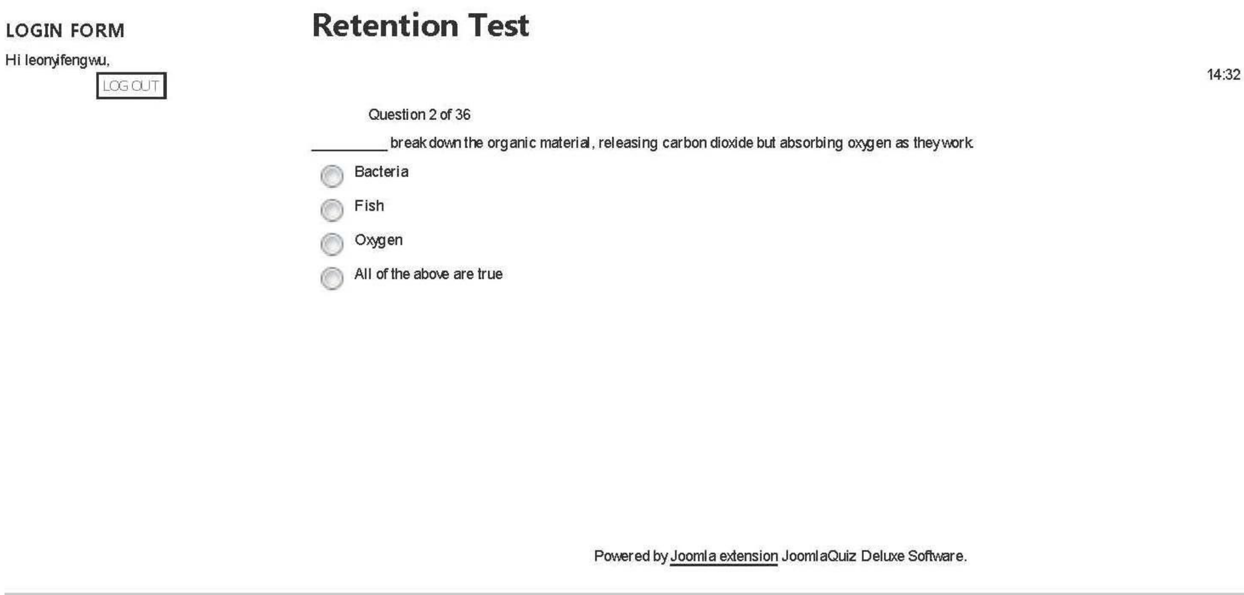
Beginning Page



Sample Question One



Sample Question Two



LOGIN FORM

Hi leonyifengwu,

LOG OUT

Retention Test

14:32

Question 2 of 36

__________ break down the organic material, releasing carbon dioxide but absorbing oxygen as they work.

- Bacteria
- Fish
- Oxygen
- All of the above are true

Powered by Joomla extension JoomlaQuiz Deluxe Software.

APPENDIXD

SURVEY

Beginning Page

Survey

Please think about each statement in relation to the instructional materials you have just studied and indicate how true it is.

Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear.

Think about each statement by itself and indicate how true it is. Do not be influenced by your answers to other statements.

Use the following values to indicate your response to each item.
1 (or A) = Not true
2 (or B) = Slightly true
3 (or C) = Moderately true
4 (or D) = Mostly true
5 (or E) = Very true

Sample Question

Survey

03:47

When I first looked at this lesson, I had the impression that it would be easy for me.

- Not true
- Slightly true
- Moderately true
- Mostly true
- Very true

All Survey Questions

- When I first looked at this lesson, I had the impression that it would be easy for me.
- This material was more difficult to understand than I would like for it to be.
- After receiving the introductory information, I felt confident that I knew what I was supposed to learn from this lesson.
- Many of the contents had so much information that it was hard to pick out and remember the important points.
- As I worked on this lesson, I was confident that I could learn the content.
- The exercises in this lesson were too difficult.
- After working on this lesson for awhile, I was confident that I would be able to pass a test on it.
- I could not really understand quite a bit of the material in this lesson.
- The good organization of the content helped me be confident that I would learn this material.

APPENDIX E

INITIAL THREAD FOR STUDENT DISCUSSION BOARD ACTIVITY

Thanks again for participating in the study. We are going to have a follow-up discussion on the activity we just did. For the initial posting, try to reflect on the multimedia project you did previously. Is there any connection between the idea of multimedia and your classroom teaching? Try to think about the following statements. Are they true? If so, why?

- When I first looked at this lesson, I had the impression that it would be easy for me.
- This material was more difficult to understand than I would like for it to be.
- After receiving the introductory information, I felt confident that I knew what I was supposed to learn from this lesson.
- Many of the contents had so much information that it was hard to pick out and remember the important points.
- As I worked on this lesson, I was confident that I could learn the content.
- The exercises in this lesson were too difficult.
- After working on this lesson for awhile, I was confident that I would be able to pass a test on it.
- I could not really understand quite a bit of the material in this lesson.
- The good organization of the content helped me be confident that I would learn this material.

You are welcome to throw out any ideas and thoughts on the video you watch. The appropriate length of your initial posting should be at least 2 paragraphs. Please also respond to at least 2 other postings.

APPENDIX F

INVITATION WEBPAGE

Hi! My name is Yu-Feng Wu. I am a doctoral student in the department of Educational Technology, University of Northern Colorado. I am conducting a research that examines the effect of text designs in a multimedia learning environment.
Your participation is voluntary. I will explain in detail in the following page about how the process of the research will be conducted in order to ensure your confidentiality, to minimize your risk, and benefits you may gain, and the contribution to education.

Please be prepare to spend approximately 1 hour on this activity.

Thank you for your participation!

Please login with your assigned Username and Password.

Important Note.

This activity MUST be completed using a Firefox or Google Chrome or Safari (Mac only) browser.

If you have one of these, you may use your own computer. If you only have Internet Explorer you will need to either download one of the listed browsers or use the MAC computers in the McKee Lab.

The activity includes video.

If you plan to work in the McKee Lab, you will need **headphones** to complete the activity. If you don't have any, contact Dr. Williams.

Link to download browsers.

Firefox: http://www.mozilla.com/en-US/firefox/

Google Chrome: http://www.google.com/chrome/intl/en/landing_chrome.html?hl=en

STAGES OF THE COURSE

Expand all Collapse all

CONSENT FORM

START

GENDER

CARD ROTATION

CUBE COMPARISONS

VIDEO ANCR

RETENTION TEST

SURVEY

APPENDIX G

CONSENT FORM

UNIVERSITY of NORTHERN COLORADO

Informed Consent for Participation in Research

University of Northern Colorado
Project Title: An Exploration of Concise Redundancy Design in Online Multimedia Learning

Researcher: Yu-Feng Wu, Educational Technology
This e-mail address is being protected from spambots. You need JavaScript enabled to view it
Phone Number: 970-626-6227

Advisor: Jeffrey Bauer, PhD, Educational Technology
Phone Number: 970-351-2368

Hi! My name is Yu-Feng Wu. I am a doctoral student in the department of Educational Technology, University of Northern Colorado. I am conducting a research studying the effect of text designs in a multimedia learning environment. With this study, I will observe the relationships among applying the text design, animated/static visualizations, learner confidence, spatial ability, and learning outcome.
To specify, at first, you will be given a general survey indicating gender information. Second, you will receive a spatial ability test. Third, you will go through a series of multimedia lesson addressing on earth science. Forth, you will receive a quiz regarding the materials you have received. Finally, you will receive a survey to assess your attitude toward the overall design of the multimedia lesson. It will take approximately 60~70 minutes to complete the whole process.
Risks to you are minimal. A maximized confidentiality of your participation will be ensured thoroughly. All your responses will be sent through online anonymously. You may feel anxious when taking the tests because they are timed. But please no worry as we are trying to minimize these feelings because the result will have no bearing on your final grades or any other academic data. The benefits to you include gaining experience for integrating multimedia in your future teaching, and practicing learning theories when they are applied in instructional design. As a reward for you to participate in this study, you will gain some extra credit in this class.
I will be more than glad to discuss with you about the result of this research for helping our future teaching and students learning experience in educational technology. Your participation is greatly appreciated which will help instructional design in multimedia related educational research.
Thank you again for your participation!

Sincerely,
Yu-Feng Wu

Participation is voluntary. Participation (e.g., complete the whole process) indicates the consent. This written consent is for your copy. You may decide not to participate in this study and if you begin participation you may still decide to stop and withdraw at any time. Your decision will be respected and will not result in loss of benefits to which you are otherwise entitled. Having read the above and having had an opportunity to ask any questions, please complete the survey and test if you would like to participate in this research. By completing the survey and test, you will give us permission for your participation. You can print this page for future reference. If you have any concerns about your selection or treatment as a research participant, please contact the Office of Sponsored Programs, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-2161.

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