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# An Investigation of Multimedia Instruction, the Modality Principle, and Reading Comprehension in Fourth-Grade Classrooms

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# AN INVESTIGATION OF MULTIMEDIA INSTRUCTION, THE MODALITY PRINCIPLE, AND READING COMPREHENSION IN FOURTH-GRADE CLASSROOMS

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Dissertation Abstract

An Investigation of Multimedia Instruction, the Modality Principle, and Reading Comprehension in Fourth-Grade Classrooms

Elementary-school teachers are faced with the responsibility of finding the most effective ways to educate their students using multimedia approaches. The use of instruction with visuals and audio has resulted in positive learning outcomes on retention and transfer tasks for junior-high and high-school students. This approach that results in the modality principle has been tested less frequently in elementary-aged students.

The purpose of this study was to examine two different multimedia instructional approaches to investigate which condition offers beneficial learning outcomes through recall and transfer assessments during a lesson on different types of energy in fourth-grade classrooms using a Powerpoint® presentation. In addition, reading-comprehension levels were studied to investigate how students with varying reading levels performed on recall and transfer tasks when presented with an audio or visual presentation. The independent variables were the method of instruction including visuals with auditory information and visuals with written text and reading-comprehension scores from a previous assessment. The dependent variables were student performance on recall and transfer assessments.

Results from the study were not statistically significant for the method of multimedia instruction overall on both dependent variables and for three different reading levels. Students who received multimedia instruction with visuals and written text and with visuals and audio performed similarly on recall and transfer tasks.

Results suggested that both methods of multimedia instruction, visuals with text and visuals with audio, can be used in elementary-school classrooms with similar outcomes on recall and transfer tasks. These results translate to students at different reading levels as well. When teachers are preparing or choosing lessons for elementary-aged students, a visual text or audio approach may benefit their students in similar ways.

This dissertation, written under the direction of the candidate's dissertation committee and approved by the members of the committee, has been presented to and accepted by the Faculty of the School of Education in partial fulfillment of the requirements for the degree of Doctor of Education. The content and research methodologies presented in this work represent the work of the candidate alone.

| | |
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# CHAPTER I

# INTRODUCTION

The global emergence of technology has prompted teachers to use instructional approaches that involve multimedia learning in elementary-school classrooms. Multimedia material is being used increasingly as an aid to teaching, whether in the form of online courses or slideshows (Jamet, 2013). Multimedia learning is one way of learning that frequently is used and defined as learning from pictures in dynamic or static form and words that can be written or spoken (Mayer, 2008). The use of technological devices such as computers and tablets serve as a way to offer pictures, text, and sound in one place, and for this reason, they are often used as the medium for delivering multimedia instruction.

Recent studies have found that multimedia and technology has a positive effect on learning across kindergarten through high-school educational settings in a variety of school subjects including mathematics, reading, geoscience, and biology (Barnett, 2003; Cheung & Slavin, 2012). More specifically, multimedia instruction has been suggested to be effective for learning complex subjects such as science (Ardac & Akaygun, 2004; Chang, Quintana, & Krajcik, 2010; Ercan, 2014; Tasci & Soran, 2008), because teaching with multiple representations facilitates and strengthens the learning process by providing several sources of information (National Council of the Teachers of Mathematics, NCTM, 2008).

Teacher awareness of the most effective instructional practices with regard to multimedia is an integral part of the learning process for students. Researchers pointed to a lack of confidence that is related to a lack of competence on the part of teachers when attempting to integrate and develop multimedia lessons (Choudhary & Bhardwaj, 2011). Teacher knowledge with regard to the wide range of technologies available can support content to be taught and identify the best pedagogical approaches to fit instructional purposes (Webb, 2005). This link between content, pedagogy and technologies has been described as technological, pedagogical content knowledge (TPCK; Koehler & Mishra, 2005). In order for effective teaching and learning to take place, a partnership should exist between curriculum, teaching practices, and technological resources in the classroom. At the forefront of this framework is knowledge and awareness regarding the most successful pedagogical processes. Through current and future research, this knowledge can be revised and expanded upon.

According to the multimedia approach, an important goal of the science of instruction is identifying how various instructional methods prime cognitive processing during learning that result in meaningful learning outcomes. Mayer (2014) stated that instructional messages should be designed in light of how the human mind works. Specifically, with multimedia presentations, it is useful to understand how learners mentally integrate words and pictures. A goal of instruction can involve presenting words and pictures in a way that fosters active cognitive processing in the learning (Mayer & Moreno, 1998). More recently, researchers continue to work toward this goal of effective processing by using instruction with words and pictures as multimedia continues to evolve (Moreno, 2006; Witteman & Segers, 2010). Consequently, if teachers are aware of or knowledgeable about the most successful instructional approaches with regard to multimedia, they may be able to deliver more effective instruction to their students. Researchers have studied and inquired about this level of awareness. According to Balanskat, Blamire, and Kafola (2006), teachers have a positive perception of technological tools, but strategies for the effective use and delivery of instruction when employing these tools are still developing. In a study by Bektas (2013), which examined teacher attitudes toward technology, 37% of teachers expressed that they did not receive inservice training concerning instructional technologies and methods. Increased awareness of successful pedagogical practices that promote deeper learning can allow teachers to promote learning for their students in ways that result in successful cognitive processing. Understanding the ways in which students learn can allow teachers to implement practices that contribute to deeper learning. Researchers continue to study the most effective instructional strategies that lead to positive learning outcomes for students (Crooks, Cheon, Inan, Ari, & Flores, 2012; Ferreira, Baptista, & Arroio, 2013). In addition, Mayer (2014) called for a research-based understanding of how people learn from words and pictures and how to design multimedia instruction that promotes learning.

Due to the realization of the importance of pedagogy when selecting or designing multimedia lessons, an extensive amount of research has been completed on multimedia instruction using middle-school, high-school, and college students as participants (Leahy & Sweller, 2011; Mayer & Moreno, 1998; Witteman & Segers, 2010). One discrepancy with this body of research involves conflicting information regarding the structure of multimedia presentations. Some researchers suggest that presenting visual information with descriptive audio rather than written text can result in a learning effect called the modality principle (Clark & Mayer, 2008). This occurrence of increased working-memory capacity due to the use of a dual rather than single mode of presentation has been researched as a medium for delivering instructional information. This principle suggests that learning will be enhanced if textual information is presented in auditory format rather than visual text accompanying related visually-based information such as a graph, diagram, or animation (Ginns, 2005). Researchers indicated that this beneficial outcome when students are presented with words and pictures rather than text may take place due to the dual coding theory (Paivio, 1986), which contends that there are separate channels for the processing of visual and verbal presentations and works under the assumption that the amount of processing that can take place in each channel is limited. Therefore, if information is split between the two channels, more effective processing may take place. An example of this effect was suggested in a study by Mayer and Moreno (1998), when learning outcomes with regard to retention and transfer were prominent when students were presented with auditory information accompanied by animations compared with students who received instruction with written text and animations in two different experiments. Additionally, in a meta-analysis by Ginns (2005), the results of a majority of studies indicated that students who learned from instructional materials using graphics with spoken text outperformed those who learned from graphics paired with written text. When a total of 43 studies were analyzed, 34 studies had an effect size of .51 or greater, pointing to strong support for the modality effect.

Although a number of studies have shown the appearance of the modality principle in the results, other studies have shown that there may be benefits of delivering pictures and written text, which has been termed the reverse modality effect and is the result of a number of studies that hypothesized the appearance of the modality principle (Crooks et al., 2012; Tabbers, Martens, & Merrienboer, 2004). In a study with sixth-grade students, for example, a reverse modality effect was experienced when students were presented with complex text accompanied with pictures when compared with the presentation of pictures and audio (Leahy & Sweller, 2011). Often, researchers hypothesize that this effect may take place due to the complexity of material or the pace of presentation (Mann, Newhouse, Pagram, Campbell, & Schulz, 2002, Tabbers et al., 2004). Pace of presentation has been given the name of a boundary condition (Rummer, Schweppe, Furstenberg, Zindler, & Scheiter, 2011) or the reason why the modality principle may not have been observed in a particular study. In many studies where the reverse modality effect was observed, researchers suggested that, when students are given the capabilities to control the pace of the presentation, they perform better when given written text because of the availability of processing time (Segers, Verhoeven, & Hulstijn-Hendrikse, 2008). Although user pace and complexity of material are often used as possible explanations for the reverse modality effect by researchers (Crooks et al., 2012, Savoji, Hassanabadi, & Fashipour, 2011, Witteman & Segers 2010), questions about the most effective ways to deliver multimedia instruction remain, especially in the elementary grades due to the limited amount of research available.

The differences in study results cited above may create confusion for teachers and instructional designers when choosing lessons that allow for the most beneficial outcomes for students. Compounding this difficulty is the lack of research completed using elementary-school students as participants. The majority of research related to the modality principle has been conducted with high-school and college students. For these reasons, a study on multimedia instruction in an elementary-school setting is warranted. This study examined the modality principle in an elementary-school setting to learn if students retain and transfer information more effectively with visuals and audio in comparison with visuals and written text. In addition, established reading levels were studied to investigate if there were differences in results with regard to students at different reading levels. It may be possible that students who struggle in the area of reading may benefit from instruction that offers pictures and audio information. Results from this study may enable elementary-school teachers to choose or design materials that result in more meaningful outcomes for their students.

## Purpose Statement

The purpose of this experimental study was to examine two different multimedia-instructional approaches to investigate which condition offers beneficial learning outcomes through recall and transfer assessments during a multimedia lesson on different types of energy in a fourth-grade classroom. The independent variable was the method of instruction including visuals with auditory information for one group and visuals with identical information only presented in textual form for another group. The dependent variable was student performance on recall and transfer assessments. Students were asked to recall relevant information from the instruction and transfer that information to new experiences immediately after the lesson. The design was experimental with random assignment within classes and took place in three fourth-grade classrooms with a sample size of 74 students in total. Two groups received visuals and audio or visuals and text during a teacher-paced lesson. Reading-comprehension scores from a previous assessment also were used in this study. The researcher used the IOWA test of Basic Skills for reading-comprehension scores for each participant as a measure of prior knowledge and investigated how students with varying reading-comprehension levels performed on recall and transfer activities when presented with an audio or visual presentation. The researcher was interested to learn if students with different reading levels perform different on recall and transfer tasks when presented with visuals and text or visuals and audio.

## Significance of the Study

This study is important for a number of reasons. First, with the emergence of multimedia instruction and learning, it is beneficial for teachers to understand the most effective ways of presenting multimedia lessons. A body of research has established a number of benefits of using multimedia in the learning of school knowledge (Schnotz & Kulhavy, 1994; Schnotz, Mengelkamp, Baadte & Hauck, 2014; Van Sommeren, Reimann, Boshuizen, & de Jong, 1998). An increase of multimedia-design practices in the classroom may enhance teacher perceptions of practicality of newly designed technology-rich activities, contribute to how teachers integrate technology, and influence overall effectiveness or student learning (Cviko, McKenney, & Voogt, 2013). NCTM (2008) standards stated that computers serve as tools to assist students with the exploration and discovery of concepts and transition students from abstract mathematical ideas to concrete experiences. Research suggests that the use of instructional technology increases the confidence, interest, motivation, habits, and learning of students (Benson & Blackman, 2003), so the effective use of this technology is an integral part of the learning process. Multimedia learning environments also allow flexible combinations of visualizations with written or spoken language and that is considered a desirable choice for a number of teachers and contributes to an increasing amount of teachers using multimedia (Schnotz et al., 2014)

Webb (2005) suggested that teachers' pedagogical strategies are a crucial component of Information and Communication Technology (ICT) in learning and teaching. Pedagogy, which has been referred to as one of the four competencies of ICT, is focused on teacher's instructional practices and knowledge of the curriculum and requires that they develop applications within their disciplines that make effective uses of ICTs to support and extend teaching and learning (Choudhary & Bhardwaj, 2011). According to Hutinger, Bell, Daytner, and Johanson (2006), teachers need help in developing an understanding of how implementation and technology integration will affect children. It is essential that teachers be able to incorporate technologies available to them because the positive effect of technology depends on the teacher's ability to use it effectively in the classroom (Kozma & McGhee, 2003). The acquisition of technological devices in schools should be accompanied by teachers who are knowledgeable and educated on instructional-design methods and practices. Adding to the research completed on successful multimedia-design practices can aid teachers in designing effective lessons and activities that promote deeper learning for students.

In addition to the need for teachers to be educated on the latest multimedia pedagogical practices, there is also a need for more research on multimedia instruction in the elementary grades. The research conducted on high-school and college students suggests that presenting material through images conducted with audio can improve learning outcomes for students. It is not known whether these results translate to elementary-school students due to the limited research on this population. Some researchers (Rozmiarek, 2000; Shilling, 1991; Weiner, 1991) believe that positive findings from using speech in multimedia may only generalize to particular populations of learners, such as adults and older adolescents. The lack of research using elementary-school students as participants may contribute to this belief. In a meta-analysis by Ginns (2005), which focused on 43 studies related to the modality principle, only seven studies were focused on elementary-school students, and those studies were conducted with students approaching and within junior-high school. According to Witteman and Segers (2010), most research related to the modality principle has been completed on adults in laboratory settings rather than classrooms. A study completed with elementary-school students as participants in traditional elementary-school classrooms could add to the knowledge base of teachers when selecting and designing lessons for their students. In addition, results from this study may encourage instructional designers to create lessons and multimedia opportunities that utilize visuals in correspondence with auditory information.  Although multimedia has received attention from researchers, it is also important to note when and under which conditions, the use of multimedia is warranted.  This study can help teachers decide whether multimedia may influence students in a positive way at this grade level.

Also, more information on cognitive processing related to the modality principle may contribute to a small amount of scientific research related to the way that young students process information. There is little research about working-memory components involvement in lessons with younger students during multimedia lessons.  Researchers suggested that the dual task and channel methodology offers a complexity that differs from other basic scientific experiments (Schuler, Scheiter, & van Genuchten, 2011).  Mayer (2008) stated that there is a reciprocal relation between learning theory and educational practice in which the science of learning must be expanded to be able to explain how learning works in authentic situations and science of instruction must be expanded to consider conditions for each instructional principle based on the understanding of how the human mind works.  Because a large amount of instruction currently takes place with multimedia, a study researching the modality principle in young students can add a more informed understanding of how young students process information in a classroom setting.

Results obtained from this study can contribute to positive outcomes related to student learning.  If students process information successfully in a way that is underused, steps can be taken to integrate different instructional approaches into the classroom.  Instruction that elicits the modality principle may be a tool that is currently being underused in the classroom due to the lack of awareness of its effectiveness. More research on the subject and how it pertains to elementary-school students may help teachers make decisions with regard to better student learning outcomes. This research can contribute to knowledge on the techniques that may help students learn essential material without overloading their cognitive system.

## Theoretical Framework

A major accomplishment of psychology has been the development of a science of learning aimed at how people learn and how to present materials in ways that stimulate this learning (Mayer, 2008). This study is based on the theory of multimedia learning (Mayer, 2008), which is a theory involving ways to present information to promote deeper learning. In order to understand the need for the theory of multimedia learning, it is necessary to understand the possibilities of how the mind works. This understanding can be traced to an explanation of learning processes called cognitive load theory.

Cognitive-load theory is a theory of instructional design that attempts to explain the crucial role a student's cognitive architecture plays in learning (Ginns, 2005). A major premise in cognitive-load theory is that instructional messages should be designed in ways that minimize the chances of overloading the learner's cognitive system. Careful consideration of multimedia design principles while considering cognitive-load theory can help to maximize meaningful learning for students.

Even though the term cognitive-load theory was first coined by John Sweller in the late 1980s, its roots may be traced back to 1979 when the term "mental-load" was first used by Neville Moray. Mental-load is defined in the psychology domain as the difference between task demands and a person's ability to master those demands (Plass, Moreno, & Brunken, 2010). The mental-load construct also took into account how human physical, cognitive, and social properties may interact with technological systems, environment, and human organizations. Over the years, researchers expanded on mental load with the help of research conducted on working memory. They have concluded that other psychological factors such as demand expectations, effort expended during performance, and the perceived adequacy of performance should be taken into consideration when evaluating mental load (Eccles, Wigfield, & Schiefele, 1998; MacDonald, 2003; Thrash & Elliot, 2001).

Many similarities can be found between the mental-load construct and cognitive-load theory founded by John Sweller. As with mental load, cognitive-load theory focuses on task demand and a student's ability to master these demands. The theory suggests that learning happens best under conditions that are aligned with human cognitive architecture (Paas, Renkl, & Sweller, 2004). One of the first hypotheses raised by cognitive load researchers established a relationship between instructional methods that teachers use to promote problem solving and cognitive-load, or the mental demands placed on students by such methods (Plass et al., 2010). Much of the research involved with cognitive-load theory involves discovering approaches by which teachers can design instruction in ways that promote problem solving while taking into account the limits of what can be processed successfully by students. The theory is concerned with techniques for managing working-memory load. Cognitive-load theory has generated numerous controlled studies indicating that some instructional formats have students involved in cognitive activities that unnecessarily impose a heavy working-memory load (Leahy & Sweller, 2011). Instructional practices that attempt to minimize this load are the focus of a number of related studies. The modality principle is an example of one of these approaches.

One of the most researched areas related to cognitive-load theory involves the limits of working memory and the amount of information that can be processed due to these limits. According to Miller (1994), working memory holds about seven elements of information for about 20 seconds. In addition, typical working memory can combine, contrast, or manipulate about two to four elements of information at one time (Sweller, 2005). These limits proposed by Miller (1994) spurred Baddeley's research on working memory. Baddeley's (1986) working-memory model serves as the foundation for recent research conducted on working memory. According to Baddeley (1986), working memory is composed of multiple subsystems referred to as the phonological loop, the visuospatial sketchpad, and the central executive. Each of these systems has its own limited capacity within the area of working memory that allows the systems to work independently. Some tasks will use systems independently, whereas other more complicated tasks may use more than one system at a time. Limitations within each system involving space available for processing may interfere with cognitive processing. Specifically, presenting textual information visually is purported to overload the visual subsystem during studying illustrations due to the need to process both pictorial and textual information within the same memory subsystem (Flores, Coward, & Crooks, 2010). When written text is presented visually, it competes for visual attention with the animation or picture, therefore creating what Mousavi, Low, and Sweller (1995) called a split attention effect. When text is presented visually, the reader is forced to split his or her attention by switching his or her eyes back and forth between text and pictures that is unnecessary when the information is presented in an auditory way. A vehicle for producing such an instructional technique that utilizes more area of working memory to prevent overload is that of audiovisual presentation within the realm of multimedia learning. In this type of instructional design, the combined resources of the visual and auditory subsystems can be used to process more information and allow for utilization of more cognitive resources in contrast to visual only presentations (Brunken, Steinbacher, Plass, & Leutner, 2002). Instructional methods that make space available for processing in each system are thought to contribute to more meaningful learning.

Working memory, or short-term memory, is crucial in learning, specifically multimedia learning, because information needs to be processed in working memory before being transferred to long-term memory (Schuler et al., 2011). The processing of information in working memory takes place in a number of steps. First, the learner perceives and selects relevant information. Then, this information is organized into a coherent mental model. Through this representation, referential connections are built between individual pieces of processed information and prior knowledge (Mayer, 1997). When complex tasks are presented, an already intensive process can become even more complex. Realizing this importance, cognitive load theory mainly is concerned with the learning of complex cognitive tasks, where learners are often overwhelmed by the number of informational elements and their interactions, all of which need to be processed simultaneously.

Paivio's (1986) dual coding theory suggests that this complexity may be aided by the existence of two separate channels for the processing of visual and verbal presentations. He explained that both hemispheres of the brain are used actively in learning environments in which both visual and textual information are used. The amount of processing that can take place in each channel is extremely limited. When the visual channel of working memory is overloaded with visual text and graphics, there is less cognitive energy available to build connections between visual and verbal representations (Mayer & Moreno, 2002). The limited capacity assumption states that each channel is limited in the amount of information that it can process at one time. If information is split between auditory and visual channels rather than overloading one of the channels, more effective processing may take place. A multimedia design offers this opportunity for learning.

Related to Paivio's theory is the separate streams hypothesis coined by Penney (1989). In this model of short-term memory structure, Penney (1989) suggested that information is channeled in separate streams on the way to long-term memory and the amount of space in each stream is limited. Specifically, information presented in auditory mode is automatically encoded in both A (acoustic) code and P (phonological) code. Penney (1989) suggested that the strength of the A code that boosts the recall of recent auditory items and, therefore, produces the modality principle (Ginns, 2005). In a presentation that positioned visual text against audio, Penney (1989) found the support for this hypothesis with a study using university students. By presenting lists in visual and auditory formats, Penney (1989) found evidence for stronger recall in the auditory group that resulted in the modality principle.

For the purposes of this study, cognitive-load theory holds that if information is presented in complete visual form, the learner first must process the entirety of material in the visual channel increasing the likelihood that his or her working memory capacity will be overloaded, therefore impeding learning (Ginns, 2005). Instructional-design methods that expand the limits of working memory currently are being tested by researchers (Schmidt-Weigand, Kohnert, & Glowalla, 2010). Instructional-design delivery methods based on cognitive load theory try to reduce cognitive load as much as possible, which begins with reducing extraneous load, or extra and unnecessary information that may interfere with successful processing in working memory.

One way to reduce such extraneous processing involves the consideration of the cognitive theory of multimedia learning. Specifically, this theory attempts to specify the difficulties that may arise during learning with texts and pictures at certain processing stages and how these difficulties may be avoided by following various multimedia design principles such as the modality principle (Rummer et al., 2011). This theory of instructional design has been linked to reduced mental effort and study time during instruction and to improved performance on retention, transfer, and matching tests (Tabbers et al., 2004).

The cognitive theory of multimedia learning (Mayer, 2008; Figure 1) is based heavily on Sweller's (1989) cognitive load theory, Paivio's (1986) dual coding theory, and Baddeley's (1999) working-memory model. The two rows represent the information processing channels that will be used during this study. The five columns represent knowledge representations constructed in a learner's mind. The arrows represent the process and order in which an individual cognitively processes material.

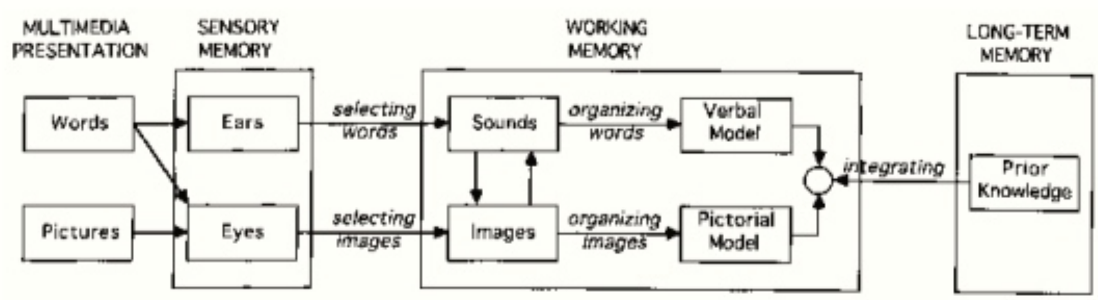


Figure 1. Cognitive theory of multimedia learning (Mayer & Moreno, 2003)

The theory of multimedia learning concurs with Paivio's dual channels approach contending that there is an auditory or verbal channel for processing auditory input and verbal representations and a visual or pictorial channel for processing visual input and pictorial representation. Consistent with cognitive-load theory and Baddeley's (1999) working-memory model, the theory of multimedia learning also suggests that each channel has limited capacity meaning that a limited amount of cognitive processing can take place in each channel at any one time. Another assumption of the theory states that meaningful learning requires a substantial amount of cognitive processing to take place in the verbal and visual channels and several types of processing must take place in order for active learning to occur. Included in this process is paying attention to the presented material, organizing this material into a coherent structure, and integrating the presented material with existing knowledge. More specifically, in multimedia learning, active processing requires five cognitive processes: selecting words, selecting images, organizing words, organizing images, and integrating these images and words with prior knowledge (Mayer & Moreno, 2003).

The cognitive theory of multimedia learning incorporates the three previously mentioned types of cognitive load into redefined types of cognitive processing as outlined by Mayer (1997) forming the basis for this theory that is referred to as the triarchic model of cognitive load in Cognitive Theory of Multimedia Learning (CTML). Extraneous cognitive processing, as it exists in CTML corresponds with extraneous cognitive load and is not related to a particular instructional goal (Kalyuga, 2011). Essential cognitive processing as defined by CTML is the processing required to represent material in working memory, is related to intrinsic load in cognitive-load theory, and is regulated by the complexity of material. Generative cognitive processing as referred to in CTML is defined as processing aimed at making sense of the essential material and can be attributed to the learner's level of motivation (Mayer, 2009). This process is related to germane load in cognitive-load theory. Here, selected words are organized into mental models and integrated with prior knowledge. When generative processing is combined with essential processing , meaningful learning outcomes is the result.

According to Mayer (1997), there are two basic goals of multimedia learning: to remember and understand information. Mayer (1997) proposed three possible types of multimedia learning outcomes: no learning at all, rote learning, and meaningful learning. He defined meaningful learning as a deep understanding of the material that includes attending to important aspects of the presented material, mentally organizing it into a coherent cognitive structure, and integrating it with relevant, existing knowledge (Mayer, 1998). Mayer and Moreno (1998) proposed 10 instructional-design principles that are based on his cognitive theory of multimedia learning. These principles are intended to foster deeper, more meaningful learning for students. One such approach involves the modality principle. His research focus is on meaningful learning, and he suggested that delivering instruction with pictures and audio that results in the modality principle is one way to achieve this outcome.

Based on the assumptions made by the cognitive theory of multimedia learning, two possible specific explanations for the modality principle can be derived (Schuler, Scheiter, Rummer, & Gerjets, 2012). The first explanation has been coined the temporal contiguity explanation and assumes that the integration of verbal and pictorial information becomes simpler when auditory information accompanies verbal information. The explanation for this assumption includes the theory that if spoken text is used to accompany a picture, listeners can listen to the presentation while looking at the picture. In contrast, if written information accompanies pictures, an extended amount of time passes due to the idea that only one source of information can be presented at a time. During this time, information is not processed due to the time lag that has taken place. Due to this assumption, it is also suggested that auditory information should accompany the corresponding picture rather than occur before or after the visual is shown.

The second assumption is referred to as the visuospatial-load explanation and contends that, in the early stages of working-memory processing, an overload occurs in the visual channel when pictures are presented with written text because both images are pictorial (Schuler et al., 2012). Due to this assumption, the use of spoken text makes additional resources available to process the learning materials. Support for this assumption was suggested by Mousavi et al. (1995) and Mayer and Moreno (1998). In experiments that tested the visuospatial-load hypothesis against the temporal contiguity explanation, students who received spoken text and visuals showed superior performance over learners with written text and diagrams both with simultaneous and sequential presentation (Schuler et al., 2012).

The modality principle suggests that learning will be enhanced if textual information is presented in auditory format rather than the usual visual format when accompanying related visually-based information such as a graph, diagram, or animation. According to the cognitive theory of multimedia learning and cognitive-load theory, the modality principle can be explained by assuming that in the initial processing stages in working memory, written texts and pictures compete for the same resources in the visual channel because both are presented visually (Schuler et al., 2011). With spoken text, however, words are processed in the auditory channel and pictures are presented in the visual channel that contributes to an effect where information has been split to expand working memory, that is, presenting information through visual pictures and only auditory text can manage essential processing by offloading cognitive processing from the overused visual channel to the underused auditory channel to avoid overloading one channel. This process has been linked to reduced mental effort and improved performance on retention and transfer tasks (Ginns, 2005).

In a number of studies that set out to focus on what may result in the appearance of the modality principle, results showed a reverse modality effect (Crooks et al., 2012; Leahy & Sweller, 2011; Witteman & Segers, 2010). When students who receive instructions with visuals and written text perform better than those who receive the auditory condition, the reverse modality effect is cited. In studies by Witteman and Segers (2010) and Savoji et al. (2011), the reverse modality effect was found when participants were presented with different instructional approaches involving visual and auditory cues. In another study by Mann et al. (2002), there was no difference between two groups that received visual and auditory instruction during a presentation that involved animations.

The two most commonly cited reasons given for a possible reverse modality effect involve the complexity of information and the responsibility of pace. Researchers have suggested that because auditory information has to be memorized before processing takes place, if the material is too long and complex, the modality principle will not take place (Leahy & Sweller, 2011). Auditory information can be considered transient, in the sense that it disappears after presentation and must be maintained in working memory for a considerable amount of time (Kalyuga, 2011). An explanation for the modality principle that is even more prevalent involves the question of user-paced or instructor-paced material. User-paced materials are referred to as possible boundary conditions that may contribute to a reverse modality effect. As recent studies have drawn attention to these potential boundary effects, the generalizability of the modality principle has been questioned (Tabbers, 2002).

Pace refers to the timing of a presentation along with the individual who has the responsibility of controlling the pace whether the individual is the student or teacher (Ginns, 2005). Multimedia presentations can be user or instructor paced. During user-paced, also referred to as simple user interaction (Mayer & Chandler, 2001) presentations, the learner has the opportunity to determine when to receive the next phase of the lesson by the press of a button. During an instructor-paced presentation, the instructor determines how long the learner will see or hear each phase of the presentation. In studies where the reverse modality effect is observed, researchers have explained that under user-paced conditions, visually presented text may be more effective because of the flexibility of use and the additional time that the approach provides (Ginns, 2005). Tabbers (2002) posited that if more time is given to learners or if they are able to control the pace of the presentation, the superiority of narration to on-screen text might be less or eliminated altogether. When Mayer and Chandler (2001) found more positive effects of reading than listening on the answering of transfer questions in a user-paced lesson, they suggested that the extra time available for study was the factor of importance.

Although user pace is often cited as a possible reason for the absence of the modality principle, studies that set out to compare a user-paced presentation with a self-paced presentation at the onset are difficult to find.

Educators have a responsibility to be aware of the most effective teaching practices that allow their students to learn information successfully. Understanding the ways in which the mind works can aide teachers when selecting or designing lessons using multimedia. Future research studies that identify techniques for presentations that minimize the load on working memory can contribute to the limited information that teachers have access to with regard to elementary-school students. It is possible that a study that strengthens the appearance of the modality effect may encourage teachers to use animations and pictures accompanied by voice. Or, if results suggest that that modality principle does not appear in an instructor-paced study, teachers may avoid using this type of instruction in the elementary-school classroom. In addition, if results suggest an extra advantage for students who struggle with reading fluency and comprehension, teachers may find an added benefit to using techniques that employ the modality principle with these students.

This study is related directly to the theories outlined above. Through the delivery of a multimedia lesson, the modality principle may or may not surface in the elementary-school setting. This study will add to the completed research on the modality principle but offered more insight into the effects of instruction delivery methods for students in the lower elementary grades. The added component of studying the results along with student reading levels can be beneficial for students and teachers. If there is an added benefit that comes with offering visual or auditory instruction for students with low, medium, or high reading levels, teacher awareness of these practices can lead to better learning outcomes for these students if used in the classroom.

This study incorporated cognitive-load theory, the theory of multimedia learning, and the modality principle in an instructor-paced environment. Instruction was given under two conditions that included diagrams and visual text and diagrams and audio in an instructor-paced condition. The participants in this study were unique to the research already conducted on cognitive-load theory and the modality principle. Although the bulk of the research has been conducted with high-school and college students as participants, this study focused on elementary-school students. In addition, the design of the study that included an instructor-paced environment is unique to the body of research that has been conducted.

## Background and Need

The emergence of the use of multimedia in society has prompted a need for teachers to understand the most effective ways that students learn when using devices such as computers and tablets. The importance of pedagogy in teaching is explained in the Technological Pedagogical Content Knowledge Framework (TPACK; Mishra & Koehler, 2006). This framework was built on Shulman's (1987) pedagogical content knowledge framework that refers to teacher knowledge of the broad principles of classroom management organization, lesson planning, implementation, and assessment. Mishra and Koehler (2006) added the technology domain to this framework. Involved in this approach is the ability of an instructor to teach content in the most understandable way. An understanding of the importance of the design of instruction is included as an integral aspect of this framework. In order to use innovative presentations, teachers must have a good level of confidence and competence (Becta, 2004). A study on the modality principle may add to the research information that teachers currently have on successful pedagogical practices.

Also, the role of teacher motivation related to instruction in the area of science has received attention from researchers. Elementary-school teachers differ from high-school and university-level teachers because teachers in elementary schools teach a variety of subjects to their students and may not be equally effective in teaching all of them. Individuals who teach in high school and at the college level often enter their professions focused on teaching a specific subject area that they may enjoy and feel more confident teaching to students. Research has been conducted with elementary-school teachers as participants and has focused on these teachers' attitudes, and confidence and how these factors may influence their effectiveness in teaching this particular subject (Crawford, 2007; Kirik, 2013). If a multimedia approach using visuals accompanied by text or audio has beneficial outcomes for students, teachers may be more likely to develop confidence in science instruction due to their familiarity with multimedia. In addition, the simplicity of finding or constructing lessons using multimedia may attract teachers to use technology in the area of science.

Results of this study may encourage leaders in preservice teaching programs to include the teaching of multimedia approaches for preservice teachers in their teacher-preparation programs. It has been suggested that these future teachers should make explicit connections between an inquiry process, their understanding of how people learn science, and their teaching practice (Crawford, 2007). Lack of confidence in the instruction of science has been a focus in a number of research studies. Lack of content knowledge in science and uncertainty related to the most effective instructional approaches and the ways to integrate these into the classroom have been cited as possible reasons for the deficit in self-efficacy among teachers.

Student motivation in science also can play a large role in learning outcomes for students. Duschl, Schwiengruber, and Shouse (2007) have argued that motivation and attitudes toward science play a large role in science learning, students' belief in their ability in science, the value they place on science, their desire to master science, and their interest in science all have consequences for the quality of their engagement in the classroom and subsequent learning. A research study that promotes multimedia learning and science may engage students who previously were less interested or motivated by the subject of science.

Although all subject areas are necessary to cultivate growth in each student, the area of science has become more of a focus for teachers as they have realized the importance of an understanding of the subject. Data on the performance of U.S. students show that many students are not well prepared in science, technology, engineering, and mathematics (STEM) fields upon high-school graduation (Nord et al., 2011). The National Research Council (NRC, 2012) indicated that the elementary-school years are an integral time for capturing and sustaining student interest in science. In a study that focused on the possible positive academic effects related to the instructional time devoted to science, Blank (2012) hypothesized that more instructional time in science would lead to higher positive achievement in science and subsequent study in science fields and in careers related to science. In this data-analysis study, the researcher used national surveys of teachers that were conducted through the National Center for Education Statistics. Results of the analysis showed that time for science instruction for grades one through four has declined from an average of 3 hours a week in 1993-1994 to 2.6 hours in 2000 and 2.3 hours in 2003 and 2008. Through an analysis conducted on different states and the amount of instructional time in science, a positive relationship was shown between instructional time and student academic achievement. A report on the status of elementary-school science education in California (Dorph, Shields, Tiffany-Morales, Harty, & McCaffrey, 2011) acknowledged a lack of opportunity for science instruction in elementary schools in the state. In this report, 40% of teachers surveyed across grades kindergarten through fifth noted that they had one hour or less of instructional time devoted to science per week. Lessons constructed similar to the one in the proposed study offer a simple way to extend science instructional time in each elementary-school classroom by providing short lessons that maximize learning opportunities.

The State of California and the archdiocese in which this study took place recognize the importance of the instruction of science and technology. Specifically, California State Standard 1g. states that students know that electrical energy can be converted to heat, light, and motion as the instructional content in this study suggests. The archdiocese has adopted these standards but has added goals related to ethics related to the fields of science and technology. The philosophy states that science instructors incorporate the use of technology and electronic resources as an integral component of student learning in science. The integration of multimedia lessons such as the one used in this study is an example of the use of technology within the subject area of science. In addition, a goal states that all students will be introduced, starting in the primary grades, to scientific vocabulary and methods, in order to provide them with the essential knowledge necessary to understand and to apply scientific concepts. A number of vocabulary words, such as thermal and electrical energy were introduced and explained during the instruction in this study.

Studies that focus on the modality principle across subject areas with high-school and college students can be accessed easily. In most of these studies, it is suggested that using pictures with an audio voice as an instructional method offers better learning outcomes than offering pictures with written text in instructor-paced environments (Leahy & Sweller; Mayer & Moreno, 1998). The collection of these studies offers much support for the modality principle. Studies that focus on the modality principle and elementary-school students are more difficult to find. This study attempted to make possible connections between these previously completed studies with older students and newer studies with younger students.

Related to the lack of investigation with elementary-school students as participants is the lack of research completed in actual classrooms. The bulk of the research has been completed in laboratory settings, and a serious criticism of the research completed on the modality principle is that most results are not based on experiences in an authentic learning environment. This study investigated the modality principle in an authentic fourth-grade classroom. An introduction of these studies that have been conducted in authentic classrooms follows.

In a study by Mousavi et al. (1995), three groups of eighth graders studied worked examples with diagrams. One group was instructed with visual text, another had auditory information, and a third group had both visual and auditory text. Results from recall and transfer assessments suggested that students in the auditory group took less time to solve problems. In this situation, it was hypothesized that the use of dual channels reduced cognitive processing load by expanding working-memory capacity. In another study by Brunken et al. (2002), results showed a modality effect caused by a possible transfer of load from the overloaded visual channel to the underused auditory channel. In a study by Leahy and Sweller (2011), sixth-grade students served as participants in an element interactivity study. When complex information was modified into smaller parts, a modality effect was witnessed through recall and transfer tasks. Witteman and Segers (2010) also studied a possible modality effect with sixth graders that resulted in superior recall and transfer scores using video and audio in a user-paced environment. In a study by Mann (1992), researchers hypothesized that students presented with auditory information other than written text would outperform students in the written-text condition. When a reverse modality effect was witnessed, researchers hypothesized that the mental processing of the participants was underdeveloped and unable to construct representations from speech prompts. Another study with elementary-school students could test the assumption that students would learn better from educational multimedia when critical information is presented as speech rather than on screen text (Mann et al., 2002).

In studies using college, high-school, and elementary-school students, the issue of the responsibility of pace and the complexity of information often play a role in the results. Trends have been witnessed when presentations are user or instructor paced. In environments where the multimedia lesson is paced by the user, a reverse modality effect is the result (Leahy, 2011; Mann et al., 2002; Savoji et al., 2011; Witteman & Segers, 2010). The reverse modality effect occurs when study participants score better on retention and transfer tasks when diagrams and visuals are paired with visual cues rather than auditory ones. In a study by Tabbers et al. (2004), participants experienced the reverse modality effect when they were allowed to process information at their own speed. Savoji et al. (2011) also found a reverse modality effect when students were given the opportunity to control the pace of their own learning. Researchers suggested that when learners can decide when to start the spoken information, it is possible to process the pictorial information separately due to the extra time that the students have to process and make connections with information. In this case, the advantage of presenting information in two different channels disappears, and the modality principle does not arise. It is possible that during system-paced instruction, students suffer between dividing attention from text and pictures given the small window of time to process the information. Studies like these bring up the importance of pace when teachers construct and deliver multimedia lessons. In situations where students are allowed to pace their own instruction, pairing visuals with audio may be unnecessary. If the presentation is instructor paced, pairing video with auditory cues may result in the modality principle. Because this study took place in an elementary-school classroom and most multimedia presentations are instructor paced for this age group, results may inform teachers of the effects of the modality principle without consideration of the added boundary effect of pace.

The complexity of information and length of text presented in a multimedia lesson may also influence student outcomes. The modality effect may be more likely to appear when information is complex (Schnotz et al., 2014). If information presented in a lesson is too simple, students may retain the information regardless of how it is presented. For the purposes of this study, the information may be complex to the students since the science components presented are new to them.

A study highlighting the modality principle in an instructor-paced environment in an elementary school is needed in order to learn if previously gained results identify with elementary-school students. Results gained may allow educators to be more educated on which lessons should be selected or created when designing lessons for students.

## Research Questions

The following research questions were addressed in this study:

1. When fourth-grade students are presented with visuals accompanied with audio instruction, to what extent does their performance on recall tasks compare with those fourth-grade students who are instructed with visuals and written text?

2. When fourth-grade students are presented with visuals accompanied with audio instruction, to what extent does their performance on transfer tasks compare with those fourth-grade students who are instructed with visuals and written text?
3. How do students with varying reading levels perform on recall and transfer tasks after being given audio or visual instruction?
4. What is the interaction effect between the modality principle and reading comprehension levels tested on recall and transfer tasks?

## Definition of Terms

The following terms are used in this study. Definitions from various authors may differ, but meanings were chosen from research studies consulted for purposes of this study and are the ones used in this study.

*Active learning* as defined by Mayer and Moreno (1998) takes place when a learner engages three cognitive processes: selecting relevant words for verbal processing and selecting images for visual processing, organizing words into a coherent verbal model and organizing images into a coherent visual model, and integrating corresponding components of the verbal and visual models.

*Animations* as defined by Butcher (2014) are visual representations that depict dynamic, moving content.

*Boundary conditions*, as referred to by Mayer (2009), are defined as the possible reasons why the modality principle is not witnessed. Boundary conditions include pacing of presentation, complexity of information, and prior knowledge of learners.

*Cognitive load theory* (CLT) as referred to by Sweller (2010) is an instructional theory based on knowledge of human cognitive architecture.

*Cognitive overload* occurs when the learner's intended cognitive processing exceeds the learner's available cognitive capacity according to Mayer and Moreno (2003). Mayer and Moreno (2003) offered the dual task and channel approach in which information is split between verbal and pictorial channels to offset the possible overload.

*The Cognitive Theory of Multimedia Learning*, as defined by Mayer (2014), is a theory of how people learn from words and pictures, based on the ideas that people possess separate channels for processing verbal and visual material. Each channel can process only a small amount of material at a time, and meaningful learning involves engaging in appropriate cognitive processing during learning.

*Dual Coding Theory* is defined by Paivio (1986) as separate channels for the processing of visual and verbal presentations and works under the assumption that the amount of processing that can take place within each channel is extremely limited.

*Element interactivity* refers to the extent to which the learning task requires the students to hold several related chunks of to-be-learned information in working memory simultaneously in order to comprehend then learn the concept or procedure (Tindall- Ford, Chandler, & Sweller, 1997)

*Extraneous processing*, as defined by Mayer (2006), is cognitive processing that wastes precious cognitive capacity but does not help the learner build an appropriate cognitive representation.

*Instructor or system-paced* lessons occur when learners have no control of the pacing of presentation of materials and the speed of speech in the presentation is considered as the maximum time needed for instruction (Savoji et al., 2011). The timing of the lesson is defined and set by the instructor.

*Long-term memory* is defined by Cowan (2001) and Miller (1994) as the part of memory where large amounts of information are stored semipermanently.

*Meaningful learning* was defined by Mayer and Moreno (2003) as a deep understanding of the material that includes attending to important aspects of the presented material, mentally organizing it into a coherent cognitive structure and integrating it with relevant, existing knowledge.

*Media* is the physical system or vehicle used to deliver instruction such as a teacher's lecture, a textbook, or computer (Moreno, 2006).

*Mental load* is the difference between task demands and a person's ability to master those demands (Moreno & Park, 2005).

*Modality is* as the sensory channel that is used initially by learners when the process information (Moreno, 2006). She also defined *visual and auditory modalities* as information presented in visual text and voice.

*Modality principle or effect*, as referenced by Ginns (2005), contends that learning will be enhanced if textual information is presented in an auditory format rather than the usual visual format when accompanying related visually-based information such as a graph, diagram, or animation. In this study, the modality principle will be apparent if students perform better on recall and transfer tasks when given instruction with pictures accompanied by audio voice.

*Multimedia* is the integration of different media such as text, graphics, animation, and sound into a computer system where appropriate (Jonassen, 2000). For this study, multimedia involves a computer presentation that uses pictures, text, and audio.

*Multimedia learning* is building mental representations between words and pictures (Mayer, 2014).

*Multimedia instruction*, as defined by Mayer (2014), is presenting words and pictures that are intended to promote learning.

The *multimedia principle*, as defined by Mayer (2014), states that people learn more deeply from words and pictures than from words alone.

*Overload*, as defined by de Jong (2010), means that at some point in time the requested memory capacity is higher than what is available.

The *personalization principle,* as defined by Mayer (2014), states that people learn more deeply when the words in a multimedia presentation are in a conversational rather than formal style.

*Reading comprehension* as defined by Van den Broek (2010) is students' ability to construct a coherent mental representation that integrates the textual information and relevant background knowledge. For this study, reading-comprehension levels were assessed by using a prior knowledge component on the IOWA Test of Basic Skills. The researcher used standard scores to assess this measure of prior knowledge.

*Recall* as defined by Scheiter, Schuler, Gerjets, Huk, and Hesse (2014) is the ability to remember information presented in learning materials. Recall was measured as part of an assessment that contained 7 multiple-choice and 3 short-answer questions. The recall portion consisted of 10 items.

*Reverse modality effect,* as referenced by Leahy and Sweller (2011), occurs when performance after visual-only presentations including text is superior to performance after visual and audio presentations.

*Schema,* as referenced by Kalyuga (2011), is a collection of organized knowledge structures that learners hold in their long-term memory base.

*Short-term memory*, as defined by Cowan (2001) and Miller (1994), is defined as the area where small amounts of information are stored for short periods of time.

*The temporal contiguity explanation* states that the mental integration of verbal and pictorial information is facilitated when text and picture can be processed simultaneously (Schuler et al., 2012).

*Temporal speech cueing* is defined by Mann (1995) as spoken information about future or past events that presents highlights or details about static or moving visuals.

*Teacher training* is the formal and informal means of helping teachers not only learn new skills but also develop new insights into pedagogy and their own practice and explore new or advanced understandings of content and resources (Choudhary & Bhardwaj, 2011).

*Transfer*, as explained by Driscoll (2005), is the application of something previously learned to a new problem or in a new context. Scheiter et al. (2014) referred to transfer as applying acquired knowledge to novel situations. Transfer performance was measured through 6 multiple-choice and 4 short-answer questions at the conclusion of instruction. There was a 10-item transfer test at the conclusion of the instructional lesson.

*User-pace* or *simple-user interaction* as referred to by Mayer and Chandler (2001) refers to user control over the amount of time that words and pictures that are presented in a multimedia explanation.

*The visuospatial-load assumption* attributes the modality effect to the fact that auditory and visual information are processed in different working-memory subsystems (Rummer et al., 2011).

*Working memory,* a place where information is stored in the brain, contains two subsystems: one for processing visual information and another for processing acoustic information (Baddeley, 1986).

**Summary**

This study investigated the modality principle in an elementary-school setting to add to the limited research base conducted on this young population. In addition, a prior knowledge measure of reading-comprehension scores was used as an independent variable to research differences and similarities on assessments with students that have varying reading levels. A literature review highlighting the modality principle and reading-comprehension studies with modality considerations is presented in the following chapter. The literature review is followed by a description of the methodology and instrumentation that were used in this study. Then, results of the study will be presented in chapter VI. In chapter V, a summary of the study, limitations, discussion, and implications for future research are presented.

# CHAPTER II

# LITERATURE REVIEW

The purpose of this study was to examine two multimedia instructional delivery techniques to investigate which condition offered more beneficial learning outcomes through recall and transfer assessments during a multimedia lesson on the different types of energy. An added component of this study involved an investigation of reading-comprehension levels for individual students. The intent of the study was to learn if there is a more effective instructional approach for those who excel in reading and those that may need additional support. Included in this chapter is a background on pedagogical considerations regarding multimedia, a background on studies performed with a focus on the modality principle, and a summary of research completed on multimedia approaches and student reading background.

## Pedagogical Considerations Regarding Multimedia

As the use of technology becomes more prevalent in society and more specifically in schools, an understanding of successful multimedia teaching practices is a necessary component for effective instruction. As teachers begin to design and select instructional information using multimedia, an awareness of well-researched attempts at instructional delivery can help teachers successfully integrate technology into their classrooms. The simple acquisition of technological devices for individual students is not sufficient to fill the need of teacher awareness and learning with regard to technology. In the rush to adopt new technology, many schools have considered bringing new media into the classroom as if the media itself was the message, but these novelties do not always involve pedagogical innovation (Kalantzis & Cope, 2010). A facilitator who is knowledgeable about the most effective instructional-design principles paired with technological tools is an integral part of the learning process. It is necessary to understand the forms of instruction that offer the most beneficial outcomes for students. A study that involves investigating a teaching practice that may facilitate positive learning can help teachers make informed decisions about lessons and multimedia activities. The results of this study could add to the research base on the modality principle and specifically add to the limited knowledge on how elementary-school students process information.

A more thorough understanding of how working-memory limitations influence learning may help teachers and instructional designers to optimize multimedia learning (Schuler, Scheiter & van Genuchten ,2011). In recognizing these limitations, researchers have begun to study instructional practices that may increase working-memory capacity. One way of expanding working memory involves utilizing techniques that may result in the modality principle. Incorporating cognitive-load theory and the theory of multimedia learning, the modality principle is an effect due to the combination of visual and auditory cues during instruction. Research that tests the effectiveness of visual and auditory instruction continues to grow due to its relationship to instructional-design principles. As research in this area continues to grow, professionals will find themselves more educated and prepared to choose and design lessons that will promote positive learning gains for their students. As teachers gain more pedagogical knowledge regarding multimedia with the aid of an increased research base in subjects such as the modality principle, they will become equipped with more tools to teach their students effectively. This literature review outlines completed studies related to the modality principle and highlights results from a variety of studies to find comparisons of teaching methods in accordance with positive educational outcomes.

## The Modality Principle

The importance of the consideration of pedagogy when choosing or designing multimedia lessons continues to be stressed by researchers as studies focused on the limits of working memory continue to grow in number. As these limits are considered, multimedia is often used as a way to expand working memory due to the availability of visual and auditory components in one place. Multimedia learning, which involves presenting words and pictures that are intended to foster learning (Mayer & Moreno, 2003), has been suggested as an instructional approach that may expand the limits of working memory. Both cognitive-load theory and the theory of multimedia learning suggest that information can enter the brain through visual and auditory channels. If information that enters working memory can be divided partially into auditory and visual components, available capacity to deal with information may be increased by using both processors rather than a single one (Leahy & Sweller, 2011). A way to expand working memory involves presenting information through multimedia with pictures accompanied by spoken words. Researchers suggested that this practice results in the modality effect and claimed that presenting visuals with auditory information rather than visual text may enhance learning and contribute to positive learning outcomes (Brunken, Steinbacher, Plass, & Leutner, 2002; Ginns, 2005; Mayer & Moreno, 1998). The modality effect is a derivative of the multimedia effect referenced above because the rationale behind the modality effect is to take full advantage of text and picture combinations by maximizing the contiguity of verbal and pictorial information or by minimizing any obstacles to the simultaneous availability of verbal and pictorial information in working memory (Schnotz, 2014). A research study examining the modality principle with elementary-school students as participants may offer guidance to teachers when they are choosing or designing lessons using multimedia.

Previous research has shown that adults and older adolescents learn better from educational multimedia when critical information is presented in speech rather than onscreen text when presented with pictures and animations (Chandler & Sweller, 1992; Mann, 1995; Mayer, 1997; Moreno & Mayer, 2002). Less is known about elementary-school students' response to this instructional technique. The following studies focus on presenting instructional methods that may allow students to retain and transfer information through multimedia with visuals and auditory text. First, studies that were conducted and resulted in the modality principle are presented. Next, studies that did not result in the modality principle or even a reverse modality effect are detailed. Although the results of these studies may be different, common themes may help with the problem of teacher uncertainty when trying to choose or design lessons that optimize learning and performance. The goal of this research is to take pieces from the following studies in order to create an instructional environment that allows for maximum learning to take place in a classroom setting.

The additional component in this study involves the use of reading scores in relation to student scores on the assessment. The last part of the literature review focuses on the limited amount of research investigating the relationship between the modality principle and reading-comprehension background. The researcher will investigate if students with different reading levels respond differently to the treatment given.

A study by Mayer and Moreno (1998) served as a model study for future research investigating the dual-processing theory. Although the study focused on university students as participants rather than elementary-school students, its importance in the body of multimedia research and its effect on studies that followed involving elementary-school students should not be underestimated. This study was the first to be completed using multimedia to illustrate the modality principle. Leahy and Sweller (2001) investigated the relationship between cognitive load and the modality of presentation with sixth graders. Mousavi, Low, and Sweller (1995) also examined the modality principle with auditory and visual conditions but used static diagrams rather than a multimedia presentation and used eighth graders as participants. This study also served as a model study for Mayer and Moreno's (1998) study using multimedia. In a study by Schmidt-Wiegand, Kohnert, and Glowalla (2010), the researchers mirrored Mayer and Moreno's (1998) study with the added component of investigating word placement in relationship to pictures. Ginns (2005) studied the results of 43 studies concentrated on the modality principle, some of which used adults as participants. The above studies are grouped together due to their similarities regarding design, and their results showing a strong positive effect for the modality principle. This research incorporated some of the design principles in these studies along with one important condition: an investigation of previously attained reading-comprehension measures and the effect that instructional approaches using the modality principle may have on these readers.

A number of studies have mirrored the format of a study that involved dual-processing theory, completed by Richard Moreno and Roxana Moreno in 1998. Mayer and Moreno (1998) stated that their study was spurred by a 1995 study by Mousavi, Low, and Sweller that involved groups of students receiving audio and visual conditions, which was the first study to use pictures along with auditory material for instruction. Using static diagrams on paper for geometry problems with 30 eighth graders, Mousavi et al. (1995) found that students learned better when auditory narration was presented simultaneously with corresponding diagrams than when printed text was presented with the same diagrams. Participants were presented with three different types of instruction. One group received visual diagrams accompanied by visual text and audio text. Another group received diagrams along with written text only, whereas the last group received visual diagrams with auditory statements only. Due to reduced cognitive load, researchers hypothesized that this last group would perform best on retention and transfer tasks. Students would be able to process the auditory statements while simultaneously attending to the diagrams. Students were given 5 minutes to solve a geometry problem. If they supplied an incorrect answer, they were asked to try again until the answer was correct. On average, the visual-visual group took 147.50 seconds to solve the first problem, the simultaneous group took 135 seconds, and the visual-auditory group only required 77.30 seconds. The effect size for this experiment was 0.93. A mixed auditory and visual mode of presenting information was more effective than the single visual mode. This group did receive as much time as needed to study examples and listen to audio. A second experiment attempted to equalize the amount of time given for study in each group. When students were timed in the amount of time that it took for them to solve problems, the visual-auditory group spent less time solving problems than the other two groups that is in keeping with the results found in experiment one. Researchers found strong support for the modality principle after conducting this study, and the effect size for this experiment was 0.88. Although the dissertation research did not offer a condition that has text, visual, and auditory in one, the modality principle was tested among two groups: visuals and audio and visuals and text as were offered in this study. Also similar to this research is the short treatment time of one class session that is common practice for most studies regarding the modality principle and multimedia.

Mayer and Moreno (1998) modified the format of the original study further by using animations rather than static diagrams in the form of a multimedia presentation. Researchers were interested to learn if the results of the previous study would extend to multimedia presentations. As is the case with the dissertation research, researchers were interested in understanding how learners integrate words and pictures cognitively. Mayer and Moreno (1998) stated that the purpose of their study was to contribute to multimedia-learning theory by testing a dual-processing theory of working memory. In a study that lasted approximately 20 minutes, one group of 40 college students viewed an animation showing the process of lightning formation using headphones (Group AN). Another group (Group AT) of 38 students received the same animations but with visual text.

The dual-processing hypothesis would claim that Group AN would recall better than Group AT on remembering steps that occur during lightning formation, choosing correct names for elements in a picture, and applying their learning to new situations in a transfer assessment. The modality principle was hypothesized to be evident because Group AN would hold the animation and narration in different working-memory spaces and Group AT would hold the animation and text in the same memory space overloading that working-memory area. Through recall and transfer assessments, this hypothesis was tested. This study was different than Mousavi et al. (1995) study in three ways. First, the animations were presented on computer rather than paper. Second, multiple dependent measures such as transfer and recall were used. Last, cause-and-effect explanations were the target material for instruction rather than geometry problem solving. These three differences went beyond the Mousavi et al. (1995) study by adding elements that catered to the current state of instruction at that particular time. Due to the emergence of multimedia in the beginning of the 21st century, researchers thought it important to use computers to deliver instruction and learn how this instruction was received by students. When synthesizing results, support for the dual-coding theory was suggested. When an analysis of variance (ANOVA) was conducted with the AN and

AT groups with the dependent measures as recall and transfer scores, statistically significant differences were found related to the split attention effect in which AN students recalled and transferred more relevant idea units than the AT students. Effect sizes were large totaling 0.89 for the retention test, medium at 0.55 for the matching test, and very large at 1.75 for the transfer test showing consistent evidence for the dual-processing hypothesis and strong support for the modality principle.

To attempt to further strengthen the results of the experiment, a second experiment was conducted. Using the same format, students studied information on how a car's braking system works under instructor-paced conditions. Again, students in the auditory condition performed better than students in the visual condition on retention and transfer tasks. Statistically significant differences were found between Group AN and AT, and effect sizes were moderate at .49 and .53 and large at .94 for retention, matching, and transfer tasks, respectively. The effect noted by this study has prompted a number of researchers to replicate the study with different materials and procedures for retention and transfer measures, which have resulted in a general recommendation to avoid the use of written text in multimedia presentations (Rummer, Schweppe, Furstenberg, Zindler, & Scheiter, 2011).

The above experiment was replicated by Schmidt-Wiegand, Kohnert, and Glowalla (2010) with an added component of contiguity effects that relate to where text is placed in relationship with a picture. In this study, researchers also tested 40 college students on the formation of lightning. The study lasted a total of 30 minutes including a pretest questionnaire, a 206-second instructional lesson, and a posttest. The auditory group, on average outscored the written groups with a mean of 15.57 (SD=1.78) on retention compared with 11.92 (SD=3.42) and 10.23 (SD=3.26). On transfer tasks, the auditory group also scored higher, on average with a mean of 3.07 (SD=0.92) in comparison with 2.00 (SD=1.41) and 1.23 (SD=0.93). The effect size for this study was calculated at .60.

In a two-experiment study with sixth graders, Leahy and Sweller (2011) also found the modality effect in one of their experiments. Researchers were interested in the effects of presenting simplified information using auditory and visual conditions in a user-paced study to investigate if a modality effect would be found. This study was similar to this dissertation research due to the decision to include participants from multiple schools but different because participants had the capacity to control the pace of the lesson. Using a two-school participant base, researchers split 24 students aged 11 and 12 years into two groups in each classroom. One group in each classroom received an audio and visual-diagram presentation and the other group received an all-visual presentation. When a 2 x 2 ANOVA was conducted on the number of correct answers to 7 questions, a statistically significant difference was found between the audio and visual and the visual only group. The audio and visual group had a mean of 51.6 and the all-visual group had a mean of 36.7. The effect size for this study was calculated at .56. In a previous experiment, however, researchers found a reverse modality effect when the material presented consisted of lengthy complex material. When lengthy material is presented in auditory form, it is possible that the auditory processing channel may become overwhelmed negating any possible modality effect. Results of this experiment are presented later.

A meta-analysis by Ginns (2005) showed strong support for the modality principle. Ginns (2005) hypothesized that presenting instructional materials using auditory information coupled with visuals would be more effective than presenting all the information in visual format. Although 43 studies were investigated, only nine of them could be found with individuals younger than high-school age. Regardless of age, effect sizes ranged from -0.66 to 2.52 with 34 of the 43 studies showing an effect size for the modality principle of 0.50 or higher. Average effect size for students in elementary school was found to be 0.51, which is moderate. Ginns (2005) also suggested that boundary conditions such as pace of presentation and element interactivity may have played a role in the results. He stated in one of his hypotheses that the strength of the modality effect specifically may be moderated by user pace. He expected a strong effect for system-paced materials but a lesser effect for user-paced materials. Studies that were coded included 31 system-paced presentations and 7 self-paced presentations. Effect sizes for the system-paced presentations were averaged at 0 .93, a large effect and effect sizes for self-paced presentations averaged -0.14.

During self-paced presentations, students may construct schema representations with the extra time available to them thereby reducing the chances for the appearance of the modality principle. Although this assumption is often noted as a possible reason for the absence of the modality principle, a study that sets out to test these assumptions at the onset has not been found. In the future, when more research has been completed on elementary-school students, this is an area of research that may receive much attention. As mentioned previously, this instructional lesson was designed as a teacher-paced lesson. Students at this age are most often given lessons that are moderated and paced by the teacher.

## The Absence of the Modality Principle: Boundary Conditions

A number of researchers who hypothesize the materialization of the modality principle find that the modality principle did not surface in a number of situations (Leahy & Sweller 2011; Mann, Newhouse, Pagram, Campbell, & Schulz, 2002; Segers, Verhoeven, & Hultstijn-Hendrikse, 2008). The emergence of boundary conditions, referred to by Mayer (2009), have been suggested as possible reasons why the modality principle has not been witnessed. These conditions include the pacing of presentation, prior knowledge base, and element and subject matter difficulty and interactivity.

### *Pace of Presentation*

Results in favor of the success of the modality principle are robust. It is possible to further this understanding of the positive effects of the modality principle by allowing learners to have the control over the pace of their performance. A lesson that couples visuals with audio and is paced by the learner may allow for deeper understanding. Simple user interaction, as referred to by Mayer and Chandler (2001), may affect cognitive processing during learning and the cognitive outcome of learning. Giving the option of user pace can negate the modality principle. If students are given large periods of time to study pictures and text, their cognitive system may offer opportunities for segmenting pieces of the presentation that may lead to better recall. Students who also are able to read text for long periods of time may choose to reread the text, and this extra reading may lead to better recall. The pacing of instruction can have an effect on the amount of subject matter recalled and transferred by students. In most cases, when elementary-school students are presented with a multimedia lesson, that lesson is instructor paced. It is easier for the teacher to manage, and minimal amounts of information allow for all students to have enough time to read and process the material.

Presentations can be instructor or user paced. In an instructor-paced presentation, the instructor is responsible for setting time parameters regarding the amount of time that participants can view and examine each picture or animation. Often, instructors will put a t limit on the time that students can view each slide. In a user-paced presentation, users are given the opportunity to continue when they are ready to advance to the next phase of the presentation. For example, they may press a button when they are ready to advance to the next visual. Numerous studies have shown that responsibility of pace may have an effect on student recall and transfer performance (Crooks, Cheon, Inan, Ari, & Flores 2012; Mann et al., 2002; Savoji, Hassanabadi, & Fasihipour 2011; Tabbers, Martens, & Merrienboer, 2004; Witteman & Segers, 2010). Often, these presentations are used with older students due to the length of material and the amount of time needed to read and study text and visuals at that level. In these studies, the possible explanation for a reverse modality effect due to pace was presented at the end of these studies.

Mayer and Chandler (2001) pointed out that conventional practice in many multimedia lessons is to show the entire presentations first with no user control followed by individually segmented pieces of the same presentation. Viewing the presentation in its entirety allows the students to be familiar with the material before receiving indepth information on the topic. Another approach would be to show the segmented information first followed by the presentation in its entirety. It is suggested that when this approach is used, the learner is unable to build a unified context related to the material. This approach would be approved by cognitive-load researchers because learners would be more likely to experience cognitive overload when the whole presentation is given first. When parts are presented under learner control, learners can chunk information into different model groups especially when learning about processes.

Researchers pointed to a number of reasons for the explanation of the absence of the modality effect in a user-paced environment. Schmidt-Wiegand et al. (2010) wrote that when accompanying text is presented with pictures, students pay less attention to the pictures due to the limited amount of time given to process all the information. When students are given the opportunity to pace their own learning, they spend more time studying pictures and text thereby producing a reverse modality effect because the extra time allowed for more processing space and time. Under self-paced conditions, time is available to transfer critical information from working memory to long-term memory and so eliminate effects that would contribute to a working-memory overload in an otherwise instructor-paced presentation (Leahy & Sweller, 2011). These researchers inferred that the superiority of graphics with a spoken-text presentation over graphics with written text under system-paced conditions disappeared or was reversed when students were given the opportunity to set their own pace through the instructional materials (Ginns, 2005).

Mayer and Chandler (2001) suggested that user pace or user interaction as they referred to it may effect cognitive processing during learning and the cognitive outcome of learning. User-pace capabilities may reduce cognitive load on working memory that enables the learner to build a coherent mental model. Previous multimedia research suggests that when many learning elements need to be processed and connected at the same time, cognitive load becomes high, and complex concept learning can be hindered. By breaking a presentation into parts by giving the user control of pace, deeper understanding may take place. The following studies are grouped together due to the similarities in structure and the inclination that responsibility of pace was why the modality principle was not witnessed.

Mann et al. (2002) found no differences between the experimental condition of visuals with auditory and visuals with text in a user-paced environment. Effect sizes for the modality effect were found to be higher in system-paced studies than user-paced studies. Tabbers et al. (2004) argued that modality effect found under system-paced conditions can be attributed to a reduction of extraneous cognitive load due to the temporal contiguity hypothesis, rather than the expansion of working memory. Savoji et al. (2011) and Witteman and Segers (2010) set out to study the modality principle in a learner-paced environment, and the results suggested that a modality effect did not surface. In the previously mentioned meta-analysis by Ginns (2005), strong support was found for the modality principle but these results occurred mainly in system-paced conditions. Of the 43 studies analyzed in the meta-analysis that showed strong support for the modality principle, 36 studies were instructor or system paced as referred to by Ginns (2005).

In a study using 12-year-olds as participants, Mann et al. (2002) hypothesized that students in a classroom setting would learn more from educational multimedia when spoken information was presented rather than visual information with diagrams. Although Mann et al. (2002) referred to "temporal speech cueing" as the practice of supplying auditory information with visuals, they hypothesized that this process would better enable students to focus their attention on a particular lesson. They chose primary school as the setting due to a flexible curriculum that allows an addition of content and variety of teaching methods. The instructional materials consisted of a learning system that presented visuals and short movies along with written or accompanying auditory information. Students were given the capability to repeat the material or move on to the next node whenever they thought that they were ready. In accordance with Mayer's (1997) and Mayer and Moreno's (1998) approach of using instructional material revolving around the way a system works such as bicycle pump, braking system, or respiratory system works, Mann et al. (2002) developed their material on engine combustion. After an ANOVA was conducted on groups that received audio in comparison with written text, Mann et al. (2002) concluded that statistical significance was not found on overall differences. As Mann et al. (2002) pointed out in the conclusion, the absence of an instructor-paced program may have contributed to the lack of considerable differences between the groups.

In a similar study by Segers et al. (2008), students participated in one of four types of learner-paced multimedia lessons: oral text only (O), oral text accompanied by pictures (OP), written text (W), and written text accompanied by pictures (WP). Differing from the researchers above, Segers et al. (2008) expected that the written conditions would produce greater learning effects immediately following the intervention figuring that students in the written condition would take more time to study the pictures and text. Also, the researchers were interested in a long-term learning effect that most previous studies had not included in their design. In addition, this study is one of the few that studied younger elementary-school students, had a large sample size of 113 students in comparison with other studies, and lasted longer than most studies, presenting a lesson every week for 4 weeks. When an ANOVA was conducted, the OP condition was found to produce the best statistically significant results immediately following a lesson. Although the modality effect was witnessed for short-term learning outcomes, which differ from results of Tabbers (2002) and Mayer and Chandler (2001), this effect disappeared one week after instruction was completed. In the discussion, the researchers indicated that the short-lived modality effect may have surfaced due to lighter cognitive load during processing. Researchers warned of the reverse effect found over time at the conclusion of their study.

Two years later, Witteman and Segers (2010) followed up the study above with another extended random-assignment study that resulted in more than just an absence of differences between groups. Instead, a reverse modality effect was observed. In this user-paced study, 80 sixth graders were tested over an extended period of time to add to the research base on the modality effect. Students were placed in two conditions: visual and auditory. In the visual group, students were shown pictures with simple text beneath them, and in the auditory condition, students were able to start, stop, and browse through the material at their leisure without limited time restraints. There was no time limit for either condition. Similar to the dissertation study, a presentation using PowerPoint® was displayed to students. Students were tested on three separate occasions: immediately after the intervention, a day after the intervention, and one week later. A reversed modality effect was found when analyzing the immediate assessment. Over time, that effect disappeared, and one week later there were no differences between the visual and auditory condition. It is unclear whether this effect took place due to simplicity of material, user-pace conditions, or a combination of the two. Also, because long-term retention is what instructors strive for, the decision of which method to choose with regard to visual or auditory in this particular experiment could be made either way with the same outcome being witnessed.

Savoji et al. (2011) set out to study the modality principle in a user-paced environment as well as to investigate if instructional pacing could moderate the modality effect on cognitive load and performance. Participants were 80 third graders, closest in age to those of this study. Participants were split into four groups consisting of Low Interaction Narrative, High Interaction Narrative, Low Interaction Textual, and High Interaction Textual. In addition to modality, another independent variable was element interactivity that can be referred to as the amount of interaction that each participant had with the media being used. In this study involving material on another process, lightning formation, students were able to control the pace of their learning in all conditions. The high-element-activity groups were given the opportunity to go forward and backward in the presentation, whereas the low-element-interactivity group could only pause and play. Findings suggested that no statistically significant difference was found between textual and narrative groups, which is an inconsistency with previous studies conducted on the modality principle. Again, researchers said that this inconsistency may be due to differences in the responsibility of pace.

Leahy and Sweller (2011) performed the same type of study as Mayer and Moreno (1998) completed on lightning formation with 24 primary-school students in the subject area of temperature. This study consisted of two experiments: one focused on differences in modality and the other focused on the effect of text and statement length on understanding. In the experiment focused on modality, researchers tested sixth graders using diagrams and text material within the content area of temperature. A group that was presented graphs with complex written statements was compared with a group that was presented with graphs and complex auditory statements. Although this experiment was system paced, a modality effect was not witnessed. In fact, the visual-only group statistically significantly outperformed the audio and visual group. Leahy and Sweller (2011) posited that this reverse effect was due to the complexity and amount of material displayed on each slide. The visual-only group was able to read and study the pictures continuously until the slide was changed while the audio and visual group was allowed to hear the information only once. Related to the dissertation study, it may be possible that these results would be the same or different if the design of the study was changed to a learner-paced exercise. Due to the user-paced format, researchers concluded that element interactivity was the reason for a reverse effect because previous research on the modality effect would point to a conventional modality effect in such a user-paced study.

Mayer and Chandler (2001) referred to user and instructor pace as part to whole presentation with material related to another process, lightning formation. In an experiment with students in college, they compared a whole-whole (WW) presentation in which students receive an entire presentation and then receive it again with a part-part (PP) presentation in which learners receive information in parts under their own control and then receive the presentation again. During retention assessments, students in both groups recalled information just as effectively with means of 4.86 (SD=1.66) for the WW group and 4.40 (SD=1.45) for the PP group. On the transfer test, the PP group produced more solutions on the transfer test than the WW group. In accordance with cognitive-load theory, learners who experience less cognitive load due to a segmented presentation are able to organize the presented material mentally into a cause-and-effect chain and relate the nearly learned material into prior knowledge.

Although a meta-analysis by Ginns (2005) displays results of a number of research studies showing robust conclusions in favor of the modality effect, he suggested that the strength of these results can be compromised when a presentation is user-paced. He wrote that under self-paced conditions visually presented text may be more effective because students can use the format more effectively. Students are able to read at their own pace and pay attention to different information pieces related to their own knowledge levels and prior knowledge. He hypothesized that the strength of the modality effect is moderated by the pacing of presentation, with a strong effect for system-paced materials but a lesser effect for self-paced materials. Ginns (2005) also stated that user-paced materials are not always a realistic expectation for all instructional lessons. Students simply cannot have an infinite amount of time to learn all concepts and skills. In a number or situations such as assessments, material must be processed and learned in a certain amount of time. Because self-pacing is not always viable, an acceptable alternative is to supply instruction in the visual and auditory mode if delivery must take place under constraints of time. If system-paced lessons are more frequently used, ways to present information that expand working memory can be beneficial for students. Because system-paced studies are used more frequently in the elementary-school setting, the researcher for the dissertation is interested to learn if results for the modality principle also would be evident with elementary-school-aged students.

Researchers in the studies above who have studied the modality principle and found no modality effect suggested that giving students the opportunity to control the pace of the lesson negates any modality effect that may have occurred. It is argued that when students have ample time to make connections between relevant information and prior knowledge, even participants in completely visual conditions are able to retain and transfer information just as effectively, if not better than students in auditory conditions. Although a number of studies cited above report stronger effects for the modality principle immediately after assessment, these studies also found that over time both conditions are the same with regard to learning outcomes. Because most elementary-school students receive lessons at an instructor's pace, a study that concentrates on this pacing condition should be most beneficial for elementary-school teachers when designing their lessons.

### ***Prior Knowledge***

Researchers have suggested that prior knowledge considerations can eliminate the modality principle (Kalyuga ,Chandler, & Sweller, 2000). If a reader has prior knowledge on a subject, the pictures and images will not be needed for instruction. Their background knowledge combined with written text would negate the effect. Students with higher-prior knowledge are able to chunk together previously learned information in a schema or organized knowledge structure that is held in their long-term memory base (Sweller, 1994). The opposite is true for a student with low-prior knowledge because they have not learned enough information to construct a schema. Instead, these learners possess a number of different elements in their short-term memory that have not been joined and constructed to enter long-term memory. The pictures and audio may help these students while negatively or not affecting students with high-prior knowledge.

In their study, Kalyuga et al. (2000) examined the role of experience and its relationship to instructional design, looking specifically at dual-channel instruction. They hypothesized that inexperienced learners would benefit from instruction that included diagrams accompanied by auditory information rather than a format that included diagrams with text-only format due to more available space in working memory. During the experiment, researchers trained learners to become more experienced with the information presented, expecting students become less and less dependent on auditory cues as they became more familiar with the instructional content.

In their experiment, 60 inexperienced trade apprentices received one of four instructional approaches: a diagram with visual text, a diagram with auditory text, a diagram with both visual and auditory text, or a diagram only using a computer program. Participants were tested and instructed in two stages, once before instruction and once after instruction was given. On the first testing session, mean scores was highest in the diagram with audio condition at 7.1 (SD=1.4). Participants in the diagram and visual text condition had a mean of 5.8 (SD=1.9). Participants in the diagram only condition had a mean of 5.1 (SD=1.7). One week after the first stage, participants were tested again after instruction related to their apprenticeship. Participants in the diagram and audio, diagram and visual text, and diagram only had a mean of 6.4 (SD=2.0), 5.5 (SD=2.4), and 6.2 (SD=2.3), respectively. The effect size for this study involving low-prior-knowledge students was 0.79. These results may suggest that as students become more familiar with material, they rely less on the way that information is presented, because the highest scores were produced by students in the diagram-only condition.

Prior knowledge in the specific area of the forms of energy within the subject of science may be limited with regard to the participants in this study. The specific forms of energy are not prescribed to be taught until the fourth grade. The researcher conducted this study at the onset of the school year before this area of the science curriculum is usually taught. In addition, the researcher has spoken with the particular teachers to confirm that they had not intended to teach about the forms of energy before the study took place.

A form of prior performance that was used and analyzed for this study is student outcomes related to reading-comprehension scores on the IOWA test. These scores were used as a variable when studying relationships between the modality principle and individual student reading scores.

### *Complexity of Information and Element Interactivity*

Another boundary condition that has received interest from research is the level of complexity of the material presented. Research studies have suggested that the modality principle may be more evident in lessons where the material is more complex rather than simple. If the material is too simple, there may be no advantage to present the information in auditory form because students in a visual condition would have an easy enough time with the information regardless of the type of delivery.

Element interactivity refers to the amount of elements or ideas presented in a particular lesson and the necessary reference to other elements in order to understand a concept. Tindall-Ford, Chandler, and Sweller (1997) predicted that low-element interactivity material with low-intrinsic cognitive load would not demonstrate the modality effect because increasing effective working memory would be irrelevant under conditions where the information to be process does not create strain on working memory. Therefore, if a lesson is too simple, presenting information in an auditory manner is unnecessary because most students would understand the material regardless of presentation style. High-element interactivity refers to elements that interact and cannot be learned by themselves. Sweller (2003) said that some examples of high-element interactivity include learning the syntax of a second language, deriving meanings of words and symbols, and balancing chemical equations. The amount of relationships and connections that a concept has can contribute to its element interactivity. If a lesson is high in element interactivity, some research has shown an advantage to presented auditory material with graphics to minimize cognitive load (Sweller & Chandler, 1994). Although participants in this study did not have background knowledge on the forms of energy, the lesson would be considered low in element interactivity due to its necessary simplicity for students at the fourth-grade age.

The difficulty with determining element interactivity is that what may be complex element interactivity for one student may not be complex for another student. This level of element interactivity depends on prior knowledge and what each student has been introduced to in the past. The difficulty in finding an absolute measure for interactivity contributes to difficulties with studies that focus on the relationship between element interactivity and the modality principle (Leahy & Sweller, 2011).

### *The Personalization Principle*

Research has suggested that the type of voice used during auditory presentations may have an impact on student performance after instruction is given.

The personalization principle states that people learn more deeply when the words in a multimedia presentation are in conversational style rather than formal style (Mayer, 2014). In this style, the words “I” and “you” are used and direct comments are made to the learner to make them feel as if they are part of the lesson. The lesson constructed for this study was completed in a conversational style with relation to the personalization principle.

There have been a number of studies that have focused on this principle and the outcomes of these studies have pointed to quality retention and transfer outcomes when the personalization principle is employed (Mayer & Moreno, 2002). It is possible that a conversational style may enhance student learning as a direct result of gaining and sustaining student attention and motivation. Researchers have suggested that personalization increases the learner’s interest, and this increase can cause the learner to exert more energy and effort to engage in active cognitive processing contributing to deeper learning (Mayer, Fennel, Farmer, & Campbell, 2004).

In Mayer and Moreno’s (2002) study, referenced above, students watched a lesson on the formation of lightning in a conversational style and a formal style. A strong personalization effect was found in four transfer tasks that were given. The effect size with relation to the personalization principle was 1.05. In another study by Mayer et al. (2004) studying the human respiratory system, researchers found a statistically significant difference between two groups in favor of the personalization principle when scoring transfer tasks.

In a meta-analysis of studies that examined conversational style, Ginns, Martin, and Marsh (2013) noted a statistically significant effect of personalization on transfer performance yielding an effect size of .54. They also mentioned that a boundary condition to the personalization principle may be the length of the lesson. They suggested that the benefits of the personalization principle may exist only when the lesson is less that 35 minutes because social cues and relationships may be most important when the student is developing a relationship with the professor.

This instructional material for this study was designed with the personalization principle in mind. The researcher designed the lesson this way in order to optimize the maximum positive effects of the lesson on recall and transfer tasks

**Considerations Involving Reading Levels**

Researchers have suggested that it is important to know whether multimedia learning will be effective for all students in the same way (Scheiter, Schuler, Gerjets, Huk, & Hesse, 2014). If a particular group of students may benefit from a particular method of instruction, teacher awareness of these methods plays a pivotal role in instructional delivery. A limited amount of studies have been completed with a focus on individual-student reading levels and outcomes related to the modality principle. An awareness of practices that may be able to aid students who struggle with reading can help teachers elicit positive outcomes in subject areas other than reading. In addition to studying the modality principle for this study, the researcher also considered individual reading levels and investigate the relationship between reading levels and outcomes on the assessment. As with research completed on the modality principle, the bulk of the investigations have been conducted with older students, predominantly of high-school age. Because studies linking reading levels and the modality principle are limited, the small amount of research that has been conducted is summarized below.

In studies by Scheiter et al. (2014) and Mayer and Sims (1994) researchers attempted to make connections between learner characteristics, such as reading levels, and multimedia principles. The researcher for this study did the same during the process of investigating the modality principle in an elementary-school classroom.

### ***Reading Comprehension***

A small amount of research has been completed on the ways that current design practices and multimedia knowledge interact with students that struggle with learning. Reading comprehension, as a learner characteristic for students in this study, was an important studied component related to the groups receiving auditory and textual instruction in this investigation. It should not be assumed that reading comprehension may only be a predictor for those students receiving instruction with written text. Reading comprehension consists of more than deciphering written text and understanding what is written. McNamara and Magliano (2009) suggested that comprehension consists of more than just processes related to the encoding of written text such as identifying letters and word decoding; rather, it describes higher level processes of understanding written discourse. Van den Broek (2010) defined reading comprehension as students' ability to construct a coherent mental representation that integrates the textual information and relevant background knowledge. A review of early studies (Sticht, Beck, Hauke, Kleinman, & James, 1974) suggested an interrelationship between listening-comprehension skills and reading-comprehension. Findings would point to comparable performance on listening and reading-comprehension skills after decoding has been mastered. There is some evidence that multimedia instruction may aid students who lack reading-comprehension skills (Mayer & Sims, 1994). The following studies investigated multimedia learning, specifically the modality principle, and possible connections to reading-comprehension skills.

### *Relationship Between Reading and Listening Comprehension*

The relationship between reading comprehension and listening comprehension is a necessary topic of discussion with relation to the current study. One group received instruction in an oral manner, and the other group received written instruction. Because the acquisition of oral language precedes written language, it is hypothesized by some that elementary-school students may perform better on recall and transfer tasks when given an oral-language lesson rather than a written one. When coupled with visuals, this hypothesis would strengthen instructional beliefs related to the modality principle. This study had a measure related to reading comprehension in order to investigate differences and similarities between readers with varying reading levels and to allow the opportunity to compare individuals who have similar reading levels.

In an investigation by Diakidoy, Stylianou, Karefillidou, and Papageorgiou (2005), researchers examined differences between listening-comprehension and reading- comprehension levels for 612 students in grades 2, 4, 6, and 8 using narrative text. Researchers hypothesized that as grade level increased, the relationship between reading and listening-comprehension would become stronger and the differences would decrease. This strengthened relationship would occur due to improved decoding skills as students move through the grades. As with the current study, validity for each passage was obtained by 7 experienced teachers who rated the excerpts for topic familiarity, unfamiliar words, and text difficulty. During two class sessions of 40 minutes, students either read or listened to one narrative and one expository text. Results showed that listening-comprehension and reading-comprehension scores were statistically significantly correlated with each other at all grade levels. As grade level increased, this relationship became stronger. The means for listening and reading comprehension in second grade were .65 (SD=.14) and .60 (SD=.15), respectively. In fourth grade, means for listening and reading comprehension were comparable at .68 (SD=.13) and .69 (SD=.13). As ages progressed both means improved but by eighth grade, the reading-comprehension mean passed the listening-comprehension mean at .75 (SD=.14) and .71 (SD=.14) pointing to an improvement in reading-comprehension scores as students mastered decoding skills. The results of this study are related directly to the current study. The current study involved fourth graders as participants. At this grade level, a number of students have mastered decoding skills whereas others are still refining these skills. Adding a prior measure of reading-comprehension scores strengthened the study because results from students who perform at the same reading levels can be compared.

## The Modality Principle and Reading Comprehension

In a study by Scheiter et al. (2014), researchers set out to investigate if multimedia design principles such as the modality effect can be moderated by students' reading comprehension skills. At the time of this study, one other study was located that specifically studied the modality principle and reading-comprehension skills (Witteman & Segers, 2010). As mentioned in detail before, this was a self-paced study that led 80 sixth-grade students through a presentation of lightning formation modeled after Mayer and Moreno's (1998) instructional materials. Researchers hypothesized that there would be an interaction between retention and transfer tasks and prior knowledge, specifically reading-comprehension ability. Similar to the current study, prior-knowledge measures in reading were used. Students were tested for their technical reading ability when they had to read a card orally with 120 words in the span of 60 seconds. Researchers used a portion of a standardized test students take yearly specific to reading comprehension as another prior-knowledge measure. When results of the test were analyzed, researchers found a statistically significant positive correlation between reading comprehension in all analyses showing that it was an important predictor of success in learning. For recall and transfer questions, there was a main effect of .54 and .33 for reading comprehension indicating that children who scored higher on reading comprehension had higher scores overall. When specifically looking at reading comprehension and the modality effect, there were no interaction effects between learning that took place and cognitive measures. Researchers found no interaction between text presentation and reading comprehension.

Reading comprehension contributed to learning outcomes whether text was presented through auditory or written means. Due to these results, Scheiter et al. (2014) hypothesized that the modality effect would not be moderated by reading comprehension in their study.

The study by Scheiter et al. (2014) is similar to the current study because information was presented to groups using auditory information, visual information, and a combination of the two. In addition, recall and transfer tasks were administered immediately after instruction, and instruction was instructor controlled with regard to pace. Researchers were interested to learn if reading-comprehension skills moderated the modality effect in any way but hypothesized that there would not be a moderation of the modality principle due to the high correlation between reading and listening comprehension.

The sample size included 125 ninth-grade students. As with the current study, reading comprehension was assessed with a standardized test that students are required to take during their ninth-grade year. The test following instruction consisted of 16 recall and 16 transfer items. Beta values for immediate recall and transfer activities were calculated at 2.63 and 2.96, respectively, suggesting reading comprehension had a slight positive influence on learning outcomes. Researchers interpreted the results to mean that low-literacy learners may have difficulty with spoken text more than written text. When students are given written text, they can take more time to read and also return to other parts of the reading passage if they had difficulty with understanding previously. The researcher for the current study investigated whether this result is obtained for elementary-school students.

The researcher for the current study was interested to learn if there are any relationships between reading-comprehension skills and modality principle. Because students in fourth grade are refining their reading fluency and comprehension skills, this age group is a good match for a study involving the possible relationship between the prior knowledge measure of reading comprehension and modality principle effects.

**Summary**

Based on the research, the most effective way of presenting material is to portray pictures with auditory information to replicate the modality effect. Using this approach, all conditions for previously researched instructional methods would be maximized. The modality principle suggests that students who receive images with audio process information more effectively. As referenced above, the results in favor of the modality effect are robust in instructor-paced lessons with relatively low prior knowledge (Chandler & Sweller, 1992; Mann, 1995; Mayer, 1997; Moreno & Mayer 2002). These results are isolated only to students who are in upper-elementary school or high school. Because most instruction in the lower grades takes place at an instructor pace and prior knowledge is low, a test with the modality principle in the elementary grades is appropriate. It may be possible that this instructional approach may optimize most effective learning. The two conditions involved in the current study were visuals with instructional-paced audio, instructionally-paced visuals with written text. Examining these two conditions in one study allowed for specific interaction effects that may shed light on the most effective instructional approaches. Often, in studies cited above, reasons for the absence of a modality effect are suggested at the end of the study when attempting to explain why this absence may have occurred. For this reason, the current study set out to examine the interactions between two conditions at the onset, with the intention to learn which approach offers the most beneficial learning outcomes for fourth-grade students.

An added component of this study involves the investigation of varying reading levels and the possible effects that a lesson focused on the modality principle may have for individual students. The amount of studies conducted on the modality principle with the added component of consideration of reading levels is minimal. The studies cited above suggest that students with lower comprehension levels may benefit from instruction that utilizes pictures with audio (Scheiter et al., 2014; Witteman & Segers, 2010). Studies that examine reading comprehension and the modality principle in the elementary grades are difficult to find. Students in grades such as fourth grade are developing their reading-comprehension skills. A study that investigates the possible relationship between reading-comprehension levels and the modality principle with this age group can add to the small amount of research previously conducted.

# CHAPTER III
# METHODOLOGY

The purpose of this study was to investigate the modality principle in an elementary-school setting to learn if presenting visuals with text or audio offers beneficial learning outcomes on recall and transfer activities. Also, a prior knowledge measure of reading comprehension was investigated as a variable in this study. This chapter details the actions taken to carry out the study, including research design, information about the sample, instrumentation, treatment description, and the procedures completed for the pilot study.

As multimedia continues to take a prominent role in classroom instruction, it is important to research the methods of instruction that cater to the most meaningful learning outcomes for students. This study aimed to test two instructional approaches to determine which one may be more beneficial for students. One approach involves presenting visuals with audio and another approach presents visuals with written text. The following methodology mirrors a number of studies that have tested for the modality principle in the past. An added component was the inclusion of a previously determined reading-comprehension measure to learn how students with different comprehension levels perform on recall and transfer tasks when presented with visual or audio instruction.

## Research Design

The research design consisted of two groups who participated in a pretest and posttest before and after instruction. Instruction and assessment took place in three fourth-grade classrooms in the Archdiocese of San Francisco. After consent was granted for individual students, a sample size of 74 participants was established. Students were randomly assigned to one of two experimental groups. Each group received the same designed instruction. The only difference between the groups was that one group received visuals and visual text and the other group received visuals with audio.

One independent variable was the method of instruction including visuals with auditory information and visuals with identical information only presented in textual form. Another independent variable was a previously completed measure of reading achievement. The dependent variable was student performance on recall and transfer activities. Specifically, a 20-item multiple-choice and short-answer achievement assessment with 10 recall questions and 10 transfer questions was administered. The same assessment was used for a pretest and a posttest. The instructional portion of the study consisted of 20 minutes for both conditions. The instructional material consisted of a lesson on the different forms of energy. Assessment took place one week before and immediately after the lesson for an average of 15 minutes each administration. Students were allowed to take the time necessary to finish the assessment. The study lasted for the duration of one week. In addition, in order to investigate whether or not students with varying reading levels perform differently on recall and transfer tasks in different conditions, a previously completed reading measure was included as an independent variable for this study. The researcher used the results of the IOWA achievement test administered in September in the area of reading comprehension for this measure.

## Sample

The sample included 74 students from three fourth-grade classrooms in three different schools in the Archdiocese of San Francisco. Schools are located within 5 miles of each other. Each school is located in a middle-class neighborhood, and school families pay tuition. All students included in the study spoke and understood English as their primary language. Participants included 36 boys and 38 girls. Classes consisted of 36, 35, and 24 students for a total of 95 students but consent was only granted for a total of 74 students. In most cases of nonconsent, forms were not returned to the researcher, therefore withholding consent. There were two students in the sample with identified learning differences with regard to processing and phonemic awareness difficulties who participated in the study. Students in each classroom were assigned randomly to a visual or auditory condition. Participants for each condition were even with 37 students in the visual condition and 37 students in the audio condition. Students in the sample are prescribed the same curriculum by the district and are expected to learn material related to certain topics during the same time frame. Teachers of each class of students expressed that they had not discussed the topic of the forms of energy with their particular classes before the time of testing. In addition, the district does not call for the instruction of this material until spring.

The three groups for reading achievement were determined before the study began. The researcher used percentile scores from the IOWA Test of Basic Skills to group participants. These groupings were based on one standard deviation above and below the previously normed mean set by the testing company. Participants were considered low level if they scored in the 1st to 34th percentile, medium level in the 35th to 67th percentile and high level in the 68th to 99th percentile. There were 14 low-level, 24 medium-level, and 36 high-level students. Each student had a percentile score given to them by the testing company.

Teachers of the three classes expressed that their students were all familiar with technology and computers. Because the lesson was instructor paced, students, however, did not need this experience as they were simply asked to watch the teacher-controlled lesson. They did not need to touch the computer screen, and all students were observed by the researcher to be sure that they did not move ahead in the lesson by pressing the forward button.

**Protection of Human Subjects**

The procedures for the protection of human subjects was followed (American Psychological Association, 2010). An application was submitted and approved by the Institutional Review Board at the University of San Francisco. District approval was obtained from the superintendent, and site approval was granted by each school principal. Consent forms were obtained from the site supervisor, teachers, parents, and students who took part in the study. Parent permission was enlisted for the use of pretest, posttest, and reading-comprehension data (Appendix A). Results from the IOWA Test of Basic Skills on reading comprehension are kept confidential and stayed at each school site at all times. The researcher traveled to each school site to obtain these scores. Pretests and posttests were coded by number so that each student's assessments and reading measures remained anonymous, and the correct pretest was matched with the posttest and the percentile score of the reading assessment from the same student. The only individuals to have access to these results were the classroom teacher and the researcher. The data acquired from assessments were kept in a secure location at all times.

**Instrumentation**

The pretest, posttest, and instructional material were constructed by the researcher. Reliability and validity considerations were taken into account during the construction and are explained in a later section.

Multiple-choice and short-answer questions were used for an identical pretest and posttest. This assessment relates to the dependent variable of student achievement on recall and transfer tasks. The test consisted of 13 multiple-choice followed by 7 short-answer questions. Examples of test questions can be found in Table 1. Each multiple-choice question was worth one point and the short-answer questions were worth from one to three points, depending on the number of components included in the question (Appendix B). The researcher was not only interested in retention but also in understanding and problem solving in relation to the material. For this reason, recall and transfer tasks were constructed. Transfer questions did not come directly from the material. Instead, these questions required learners to take the information learned and apply that information to new experiences. For example, one question asked participants to name an object in their home not mentioned in the instruction that uses electrical energy.

The test consisted of 10 recall and 10 transfer questions in both multiple-choice and short- answer form. Transfer questions were not isolated to short-answer form; six multiple-choice questions were transfer. Some questions were worth more than one point so the total possible for recall questions was 12 points and for transfer questions was 14 points. During the construction of the test, an expert panel filled out a rubric concerning learning objectives met by the instructional material (Appendix C).

Table 1

Examples of Test Questions (Multiple Choice and Short Answer)

| | |
|---|---|
| A. How many types of energy are there? (1 point) | A) 6<br>B) 8<br>C) 2<br>D) 5 |
| B.What is the energy of motion called? (1 point) | A) potential energy<br>B) kinetic energy<br>C) chemical energy<br>D) thermal energy |
| C. Name two things in your school or home that use electrical energy. (2points)* | |
| D. What kind of energy does a plane have as it is waiting to take off? (1 point) | |

* denotes transfer question

The instructional lesson consisted of 20 slides that contained the instructional information (Figure 2). One version of the slide contained visuals with text, and the other contained visuals with audio.

A measure of previous knowledge consisted of each student's standard score in the area of reading comprehension on The IOWA Test of Basic Skills that each student is required to complete in September. The IOWA Test of Basic Skills is a standardized test that each student in the Archdiocese is required to complete each year beginning with second grade and ending with the eighth grade. The test spans

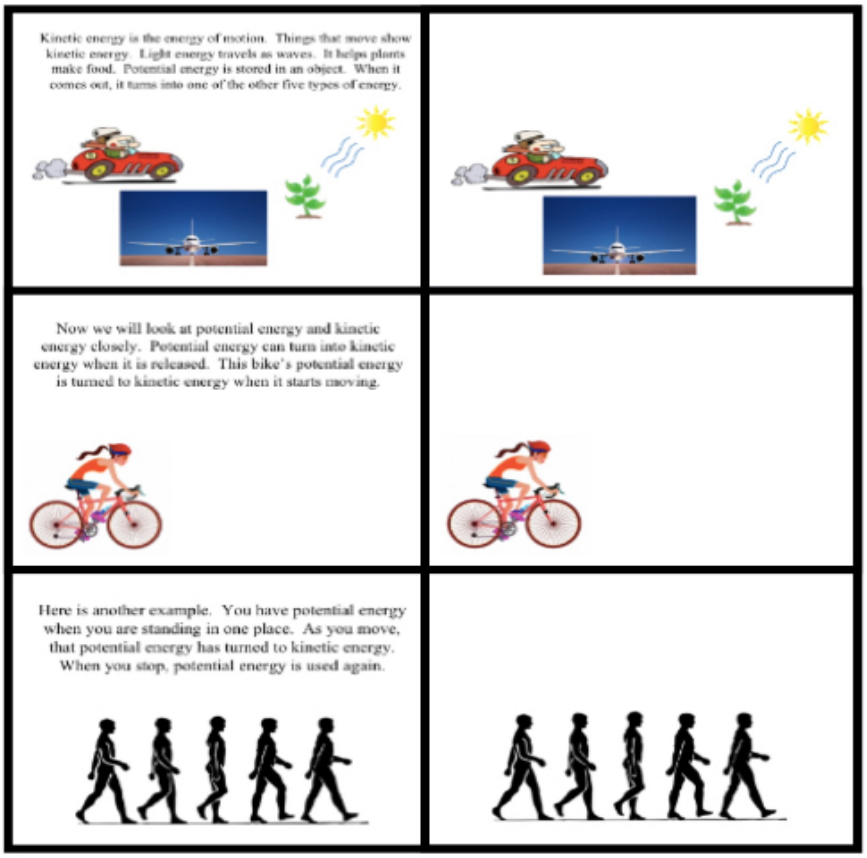


Figure 2. Example of Instructional Slides

each subject area including the curricular areas of reading, language, mathematics, social studies, and science. For the purposes of this study, the reading-comprehension subtest scores were used as an independent variable. The reading-comprehension subtest is administered in two parts and contains passages that differ in length from a paragraph to an entire page. Literary and informational passages are included, and students are asked to answer questions in multiple-choice format at the end of each passage. After the tests are administered, they are sent away for scoring, and scores are returned to the school.

The researcher used National Percentile Ranks (NPR) to group the students into three groups: low (1-34), medium (35-67), and high (68-99). National norms for the IOWA assessment were reevaluated in 2010 and 2011. Samples of schools were selected using a random sampling process to develop a national probability sample. The variables that were used to classify school districts throughout the nation were geographic region, district enrollment, and socioeconomic status of the school district. This information helped establish the norms in which the percentile ranks were based.

Students at the elementary-school age have a wide range of reading abilities. The extent of individual reading abilities may affect results on the posttest if student in the text condition had difficulty reading the material. In addition, students in the auditory condition may have had an advantage if the reading material was too difficult to read. For this reason, readability measures were taken into account during design of the study. Specific reliability actions are described below in the pilot-study summary. In addition, reliability and validity measures were used in preparation for the pilot study and are explained below.

## Pilot Procedures

A pilot study was conducted in May 2015 with a fourth-grade class in order to test procedures and gauge difficulty of material for this particular age group. In addition, the researcher wanted to test if the procedures were practical, realistic, and simple to follow for teachers and students. The class consisted of 24 students.

Participants were split into two groups of 12 students, and each individual student was assigned randomly to one instructional condition. In order to have at least 30 students to increase reliability and validity, six students from different schools were enlisted to take part in the study. The conditions included visuals with visual text and visuals with auditory information in an instructor-paced condition. Students were assessed one week before and immediately after instruction took place.

The pilot test consisted of 22 questions. Twelve of these questions were recall tasks, and 10 were transfer tasks. The test consisted of both short-answer and multiple-choice questions.

The pilot study was conducted in May and June of 2015 with 30 participants. The researcher administered each portion of the pilot study including the pretest, instructional material, and posttest. Upon studying student behavior during the study, it was determined that the time given for each slide was excessive. Each student had ample time at the end of the slide, and rather than studying the illustrations, much time was spent looking away from the computer screen. Due to this observation, slide length was reduced from 60 seconds to 55 seconds for the actual study; still allowing for sufficient time but reducing the time spent looking away from the computer screen.

After the posttest was administered, students were asked informally about their ideas about the lesson. All students said they were engaged by the material and enjoyed the pictures and animations. They also expressed that they had taken their time on the assessment and put forth maximum effort.

### *Pilot-Study Results*

One of the main purposes of the pilot study was to gauge the reliability of the testing materials. Specific procedures were conducted to test the reliability of test materials. Low discrimination for three items prompted the elimination of these questions and an addition of one new question to have a 20-question pretest and posttest for the actual study. The new question was approved by the expert panel that had been enlisted to evaluate the original pilot test.

### ***Reliability***

Reliability investigations were conducted for the pilot study and the final study in order to assess if each student would score the same on a test under the same conditions repeatedly. Reliability was calculated for the pilot tests so that adjustments could be made for the final test. Table 2 contains the reliability estimates for the pilot study and actual study. For the pilot pretest, recall and transfer reliability was poor. On the posttest, recall reliability improved but transfer reliability remained poor. Estimates increased for the actual study but marginally. Posttest reliability estimates were much higher than pretest estimates at .74 for the pilot study total and .85 for the actual study total. The short manner of the test and age of the participants may have contributed to low reliability. Transfer assessments had the lowest reliability. Students' efforts to transfer their knowledge to new situations may have contributed to a tendency to guess on the answers to questions. Three items with low discrimination were omitted from the pilot study assessment and one question was added to the actual study to make a total of twenty questions for the actual test.

Table 2

Reliability Estimates Using Cronbach Coefficient Alpha

| Measure | Pilot Study | Actual Study |
| --- | --- | --- |
| Pretest | | |
| Recall | .38 | .50 |
| Transfer | .40 | .44 |
| Total | .63 | .65 |
| Posttest | | |
| Recall | .62 | .75 |
| Transfer | .45 | .69 |
| Total | .74 | .85 |

### ***Validity***

A number of actions were taken to test the validity of the instruments to assess if each student's score would be an accurate representation of the lesson's objectives. In order to strengthen content validity, the pretest, posttest, and multimedia lesson were constructed by the researcher with guidance from the current fourth-grade science teacher at the school where the pilot took place and using the district-approved science textbook for fourth graders at each school. After the lesson was constructed, an expert panel consisting of classroom teachers was enlisted to assess whether the material included in the multimedia lesson was age appropriate. Visuals and text were assessed for appropriateness with regard to text difficulty and clarity of visual images. The panel included the fourth-grade teacher at one participating school, science teacher, and a teacher from a different school. Teachers were given rubrics to complete related to the instructional materials (Appendix C). Minor changes to wording were recommended and changed by the researcher. For example, if a word was deemed too difficult to understand by the fourth-grade teacher with consideration to her students, it was changed to a simpler term in order to ensure that all students would understand the terminology. The researcher also tested the readability of the lesson using the Automated Readability Index (ARI), and the readability was established at the 4.2 reading level, which is a match for the period of time when students were expected to take part in the actual study. An outside evaluator also listened to the audio presentation while witnessing the visual presentation to ensure that both were identical with regard to word usage. The evaluator confirmed that the audio and text matched.

The assessment for the pilot was evaluated by an expert panel consisting of the fourth-grade teacher at the participating school, fourth-grade science teacher, and a teacher from a different school. Evaluators filled out a rubric consisting of components related to appropriateness of the question and readability (Appendix C). Modifications were made to test questions with consideration of comments made by evaluators. For example, when two recall questions were considered redundant, another recall question was added in place of one of the redundant questions. In addition, when a question was deemed too vague or difficult to understand, teachers suggested another question to take its place. The questions were evaluated by the expert panel before being added to the assessment. Areas of focus included item difficulty, appropriateness of subject matter, and readability. The expert-teacher panel also was enlisted to make comments on the scoring rubric that was constructed by the researcher. When the assessment was collected, it was graded objectively according to the researcher-created rubric that was given to the expert panel for recommendations and changes (Appendix C).

## Treatment Description

A fourth-grade appropriate instructor-paced lesson on the forms of energy was designed using the ADDIE process. ADDIE, an acronym that stands for analyze, design, develop, implement, and evaluate, is a product-development paradigm based on instructional-design principles. A need for instruction on the forms of energy was established while following the Archdiocesan and state learning standards. The design was implemented in accordance with the fourth-grade science textbook prescribed by the district. The lesson was developed and implemented through a process of adding components that students would find helpful when learning complex ideas such as the forms of energy. Evaluation of the lesson was completed in the form of reliability and validity checks by an expert panel. The researcher constructed the treatment in the form of a multimedia lesson (Appendix B). Both forms of the lesson are identical with regard to word content. The differences lie in the use of audio versus text. The audio version of the lesson was recorded in the researcher's voice. Each version of the lesson was constructed using PowerPoint ®.

Two different types of instructional delivery took place during this study. One group received instruction on the forms of energy with visuals, animations, and written text displayed on the computer screen. The other group received instruction with visuals and animations displayed on the computer screen but received auditory information through headphones. Students at each school received instruction in two groups, one after the other. Students receiving the audio condition wore headphones to listen to the material. These students received the instructional material after the students in the textual condition so students in the text condition did not know that one group had received headphones. While one group received their instruction, the other group worked on a science lesson with the homeroom teacher. Teachers at each school site were trained on the directions for administrating the pretest during a meeting with the researcher. The researcher traveled to each school site to administer the instructional lesson and posttest, but the pretest was administered by the classroom teacher.

## Procedures

Participants were students in the fourth grade in three schools in the Archdiocese of San Francisco. Schools were chosen based on geographic proximity and availability of multimedia materials at each school site. Each group of students took the pretest at their school site on Wednesday of the second week of October during regular class time. The pretest was administered by each homeroom teacher who was trained on administration by the researcher during a meeting one week before giving the test. Students were divided into groups at random by a neutral individual who assigned students to each condition using a table of random numbers after obtaining all the participants at each school. Students were assigned a number by this individual and will then were split into each instructional group. Each group of students was assigned randomly regardless of their particular school. Consent for the use of scores was requested from the superintendent, principals, parents, and students at each school site. Students took part in the pretest, posttest, and instructional module during class time whether or not consent was given because the material is part of the school curriculum. One week after the pretest was given, students watched the instructional module in the computer lab in two separate groups immediately after one another. The text group watched the presentation in the computer lab and immediately took the posttest and were followed by the auditory group who were given headphones to watch the presentation. While each group was watching the instruction and taking the assessment, the other group was working with their homeroom teacher on a science activity supplied by the researcher. Both groups completed the instruction and posttests before any recesses so contact between groups was minimal. Pretests and posttest were administered through paper-and-pencil tests and were collected immediately after the tests were given. The researcher traveled to each school site to collect data on reading-comprehension scores as each school received these data from the testing company. Each school has a designated site where results from the IOWA Test of Basic Skills are kept. The researcher gained consent from principals and parents to gain access to these scores, and score reports were kept on campus at all times. The timeline for collection of IOWA test scores, and study pretests and posttests is shown in Table 3.

Students who were absent on the day of the pretest or instructional unit and posttest took the portion missed upon their return to school. If consent was not granted for an individual, they were expected to take part in the lesson and assessments, but their data were not used for the purposes of this study.

Table 3

Timeline for Data Collection

| Date Collected | Data |
|---|---|
| Thursday, October 15 | Pretests administered at each school site |
| Friday, October 16 | Pretests collected from each school site |
| Thursday, October 22 | Instruction and posttests administered and collected at school #1 |
| Friday, October 23 | Instruction and posttests administered and collected at school #2 |
| Monday, October 26 | Instruction and posttests administered and collected at school #3 |
| Thursday, November 3 | IOWA test results collected at all school sites |

## Research Questions

The following research questions were addressed in this study:

1. When fourth-grade students are presented with visuals accompanied with audio instruction, to what extent does their performance on recall tasks compare with those fourth-grade students who are instructed with visuals and written text?
2. When fourth-grade students are presented with visuals accompanied with audio instruction, to what extent does their performance on transfer tasks compare with those fourth-grade students who are instructed with visuals and written text?
3. How do students with varying reading levels perform on recall and transfer tasks after being given audio or visual instruction?
4. What is the interaction effect between the modality principle and reading-comprehension levels tested on recall and transfer tasks?

## Data Analysis

All statistical tests were assessed for meeting assumptions, and were performed at the .05 level of significance. If statistical significance was found, then effect sizes were computed. For research question one, a comparison of change from pretest to posttest provided information on possible differences in groups who received visuals with audio information in comparison with visuals and written text for recall questions. For research question two, the same analysis took place for transfer questions. For research question three, an analysis of reading levels took place. Using the results from the IOWA Test of Basic Skills taken in September, the researcher looked for similarities and differences in assessment outcomes with students with different reading levels. Percentile scores were used to place students in one of three reading levels. These reading levels were established before testing takes place. These levels were low, medium, and high.

Differences between two groups were analyzed. In order to obtain data on all research questions, the researcher used a two-way analysis of variance with instructional approaches and ability level as the independent variables and the difference between pretest and posttest recall and transfer scores as the dependent variables. For research questions numbers one and two, the main effect for treatment addressed the research questions. Research question number three was addressed by the main effect for reading levels. Research question number four was addressed using the interaction effects from the two-way ANOVA.

## Researcher Qualifications

The researcher has been a second-grade teacher for 15 years. During those years, she has participated in yearly workshops and inservices focused on instructional methods and assessment techniques. As a student at University of San Francisco, she continued to study current research and instructional practices involving technology.

# CHAPTER IV
# RESULTS

The purpose of this experimental study was to examine two different multimedia instructional approaches to investigate which condition offers beneficial learning outcomes assessed through a recall and transfer assessment during a multimedia lesson on different types of energy in a fourth-grade classroom. Students were presented with a multimedia lesson in two separate groups: one with visuals accompanied by text and the other with visuals accompanied by audio without written text. The researcher was interested in investigating pretest and posttest results to learn which group performed better on recall and transfer assessments. An added component of the study involved a previous measure on reading achievement to test whether or not students with varying reading levels performed differently on pretest and posttest tasks.

The results of the study are presented as they relate to each research question referenced in chapters I and III. First, results of pretest and posttest analysis for each instructional group is presented using an analysis of means for recall and transfer scores for visual and auditory groups followed by results for a two-way analysis of variance (ANOVA) with instructional approaches and ability level as the independent variables and the difference between pretest and posttest recall, transfer, and total scores as the dependent variables. This analysis allows for possible interaction effects between reading levels and intervention and addresses research question four.

The assumptions for the two-way ANOVA were taken into account for this study. The assumption for random assignment was met as students were randomly assigned to an instructional condition. The assumption for independence also was met as students took the pretest and posttest independently and watched the instructional lesson on their own. Normal distribution assumption for the instructional groups was not a concern as each group contained 37 participants. When students were divided into the reading levels of low, medium, and high, however, the normal distribution assumption became a concern. Low-medium-and high-reading groups contained 14, 24, and 36 students, respectively. The sample sizes of the low and medium groups are too small for the Central Limit Theorem to apply. Therefore, had statistical significance been found, there would be a risk of making a Type I error. In the cases where statistical significance was found, eta squared was computed in order to determine if a Type I error was unlikely. The homogeneity of population of variances assumption was robust for the instructional groups due to overall sample size because the sample sizes were equal. For reading levels, the sample sizes were not equal or nearly equal indicating that the assumption of homogeneity of population variances is questionable. Levene's test of equality of error variance was not statistically significant for recall and transfer scores taking reading groups into consideration.

For research questions one and two, the researcher investigated possible differences between the visual and audio groups on recall and transfer tasks, respectively. Pretest and posttest recall and transfer means and standard deviations are presented in Table 4.

For recall tasks, outcomes were similar for both groups in that large gains were seen from the pretest to the posttest. The visual group mean change was 5.14

Table 4

Means and Standard Deviations for the Pretest and Posttest Recall, Transfer, and Total Scores Broken Down by Treatment Group

| | Group | | | | | |
|---|---|---|---|---|---|---|
| | Visual(*n*=37) | | Audio(*n*=37) | | Total(*N*=74) | |
| Test Variable | *M* | *SD* | *M* | *SD* | *M* | *SD* |
| Pretest | | | | | | |
| Recall | 3.95 | 1.90 | 3.78 | 1.96 | 3.86 | 1.92 |
| Transfer | 6.54 | 2.01 | 6.38 | 2.30 | 6.45 | 2.15 |
| Total | 10.49 | 3.22 | 10.16 | 3.87 | 10.32 | 3.54 |
| Posttest | | | | | | |
| Recall | 9.08 | 2.83 | 8.32 | 3.28 | 8.70 | 3.07 |
| Transfer | 10.22 | 2.87 | 9.68 | 3.19 | 9.95 | 3.03 |
| Total | 19.30 | 5.43 | 18.00 | 6.23 | 18.65 | 5.84 |

Table 5

Means and Standard Deviations for Recall Change Scores Broken Down by Treatment Group and Reading Level

| | Group | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Visual | | | Audio | | | Total | | |
| Reading Level | *n* | *M* | *SD* | *n* | *M* | *SD* | *n* | *M* | *SD* |
| Low | 6 | 2.67 | 1.37 | 8 | 3.50 | 3.66 | 14 | 3.14 | 2.85 |
| Medium | 12 | 4.33 | 3.14 | 12 | 3.83 | 3.30 | 24 | 4.08 | 3.16 |
| High | 19 | 6.42 | 3.17 | 17 | 5.53 | 2.53 | 36 | 6.00 | 2.88 |
| Total | 37 | 5.14 | 3.22 | 37 | 4.54 | 3.11 | 74 | 4.84 | 3.16 |

and the audio group mean change was 4.54 (Table 5). Although both groups showed improvement in means on recall tasks, the visual group had a higher mean on the posttest than the audio group by less than one point. Pretest and posttest recall scores broken down by treatment groups are shown in Figure 3. Results of the ANOVA did not show an effect for method of instruction with regard to recall tasks (Table 6).

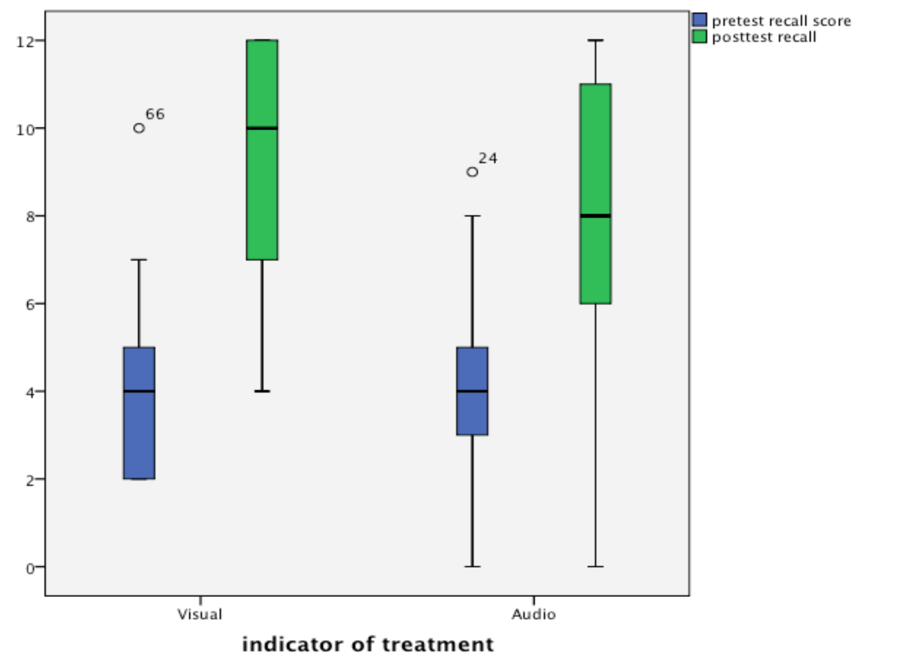


Figure 3. Pretest and Posttest Recall Scores Broken Down by Treatment Group

Table 6

Results of Two-Way ANOVA for Recall Scores

| Source | *SS* | *df* | *MS* | *F* | *eta squared* |
|---|---|---|---|---|---|
| Reading Level | 102.28 | 2 | 51.14 | 5.65* | .14 |
| Treatment | 0.54 | 1 | 0.55 | 0.06 | |
| Reading Level x Treatment | 7.41 | 2 | 3.71 | 0.41 | |
| Within | 614.53 | 68 | 9.01 | | |
| Total | 728.05 | 73 | | | |

* Statistically significant when the overall error rate was controlled at .05

For transfer tasks, participants in both groups also showed gains. The visual group had a mean change of 3.68, and the audio group had a mean change of 3.30 (Table 7). The visual group also had a higher mean than the audio group on transfer tasks. The difference between the two instructional groups on transfer measures was larger for the posttest than the pretest with the visual group outscoring the auditory group on average for both tests.

Table 7

Means and Standard Deviations for Transfer Change Scores Broken Down by Treatment Group and Reading Level

| | Group | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Visual | | | Audio | | | Total | | |
| Reading Level | *n* | *M* | *SD* | *n* | *M* | *SD* | *n* | *M* | *SD* |
| Low | 6 | 2.00 | 2.68 | 8 | 1.88 | 2.17 | 14 | 1.93 | 2.30 |
| Medium | 12 | 4.00 | 2.86 | 12 | 3.50 | 2.39 | 24 | 3.75 | 2.60 |
| High | 19 | 4.00 | 2.69 | 17 | 3.82 | 2.40 | 36 | 3.92 | 2.52 |
| Total | 37 | 3.68 | 2.77 | 37 | 3.30 | 2.41 | 74 | 3.49 | 2.59 |

Figure 4 shows the pretest and posttest scores for each treatment group with regard to transfer outcomes. When means were examined, participants scored higher on average in the visual condition but by less than one point. Results of the ANOVA analysis did not show a statistically significant effect for transfer scores by method of instruction (Table 8). These results were not statistically significant so effect sizes were not computed.

Reading levels and outcomes on recall and transfer tasks were another area of focus for this study. Students were placed randomly in a visual or auditory condition. Research question three called for an examination of recall and transfer

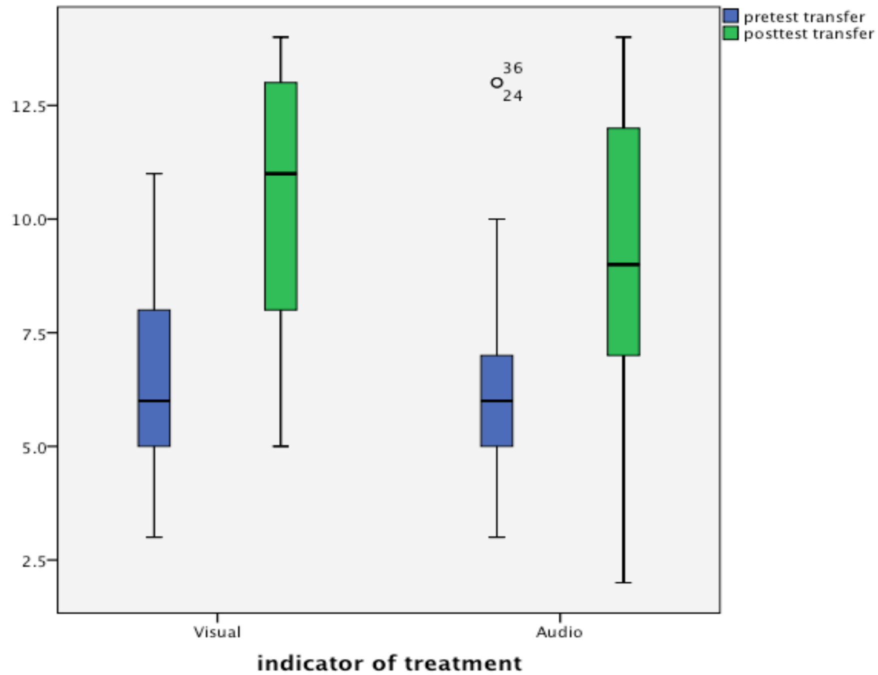


Figure 4. Pretest and Posttest Transfer Scores Broken Down by Treatment Group

Table 8

Results of Two-Way ANOVA for Transfer Scores

| Source | *SS* | *df* | *MS* | *F* | *eta squared* |
|---|---|---|---|---|---|
| Reading Level | 41.06 | 2 | 20.53 | 3.14* | .09 |
| Treatment | 1.12 | 1 | 1.12 | 0.17 | |
| Reading Level x Treatment | 0.47 | 2 | 0.23 | 0.04 | |
| Within | 444.35 | 68 | 6.53 | | |
| Total | 488.49 | 73 | | | |

* Statistically significant when the overall error rate was controlled at .05

outcomes of students with varying reading levels. The mean on the IOWA assessment test for students placed in the visual condition was 60.70 (SD=27.7), and the mean for students placed in the audio condition was 61.80 (SD=25.6), demonstrating a small difference, but not relevant, between groups before this study began. A two-way ANOVA was conducted with instructional approaches and ability level as the independent variables and the difference between pretest and posttest recall and transfer scores as the dependent variables. Change scores for each reading level and condition are presented for recall and transfer measures (Tables 5 and 7). Effects for reading levels and instructional methods were not statistically significant (Table 6). Statistical significance was found for reading levels in recall, transfer, and total scores, not taking instructional condition into consideration.

On recall tasks, low-level readers in the audio condition scored almost one point more on average than low-level readers in the visual condition. The difference decreased for the medium-level readers as outcomes for both groups were very similar and separated by less than one-half of a point. For the high-level readers, results were opposite of the low-level readers in that the visual condition change scores were almost a point higher on average than the audio condition. Recall change scores broken down by treatment group and reading level are shown in Figure 5. There was statistical significance for reading groups without consideration of type of instruction. Eta squared was computed at .14 for recall scores and reading groups, which is a large measure of practical importance.

Transfer change scores were less pronounced than recall change scores (Table 7). Changes for both conditions in each reading level were very similar. The means for the visual groups were larger than the means for the audio groups for all three reading levels on transfer scores. These differences in change scores consisted of only one-half point or less. Although not statistically significant,

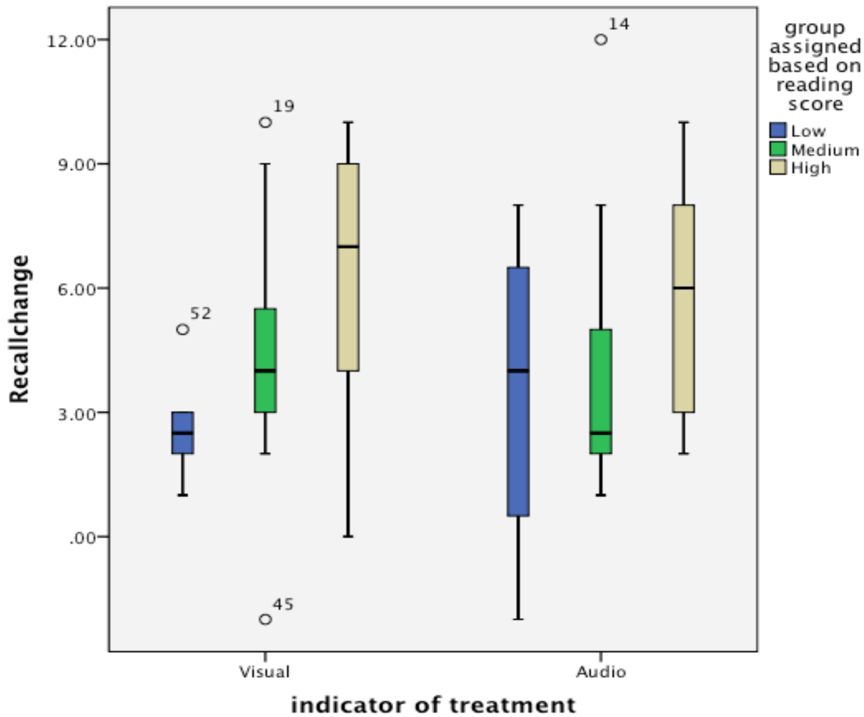


Figure 5. Pretest and Posttest Recall Change Scores Broken Down by Reading Level and Treatment Group

more positive change was seen for the visual groups. The largest difference in means was in the medium-level group, where the visual group mean for the visual group was .50 higher than the audio group mean. Transfer scores broken down by treatment group and reading level are shown in Figure 6. Statistical significance was found for reading groups without consideration of type of instruction. Eta squared was computed at .09 for transfer scores and reading groups, which is a medium measure of practical importance.

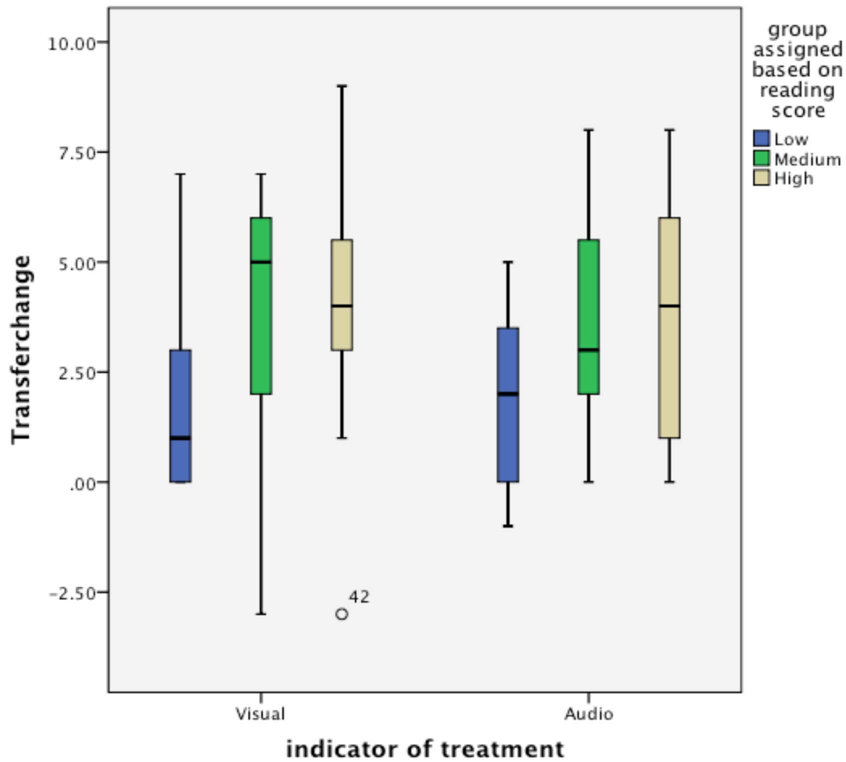


Figure 6. Pretest and Posttest Transfer Change Scores Broken Down by Reading Level and Treatment Group

For research question four, statistically significant interactions between reading levels and mode of presentation were not found for recall and transfer tasks. Again, statistical significance was found for reading levels without considering instructional condition (Tables 6 and 8). The only interaction occurred when the low-level group means were higher for the audio group than the visual group. The opposite occurred for medium-level and high-level readers as their means were higher in the visual condition. The ANOVA analysis did not reveal a statistically significant interaction between reading group and method of instruction.

## Additional Analyses

Frequencies for individual test questions also were examined (Table 9). Frequencies for the pretest and posttest show growth for every question except for one. Large gains were made for all students when examining growth question by question. On average, pretest to posttest scores showed an increase for 24 students advancing from no credit to full credit on each test question.

Table 9

Frequencies of Participants Receiving Full Credit for Each Question (*N*=74)

| Question | Pretest | Posttest | Question | Pretest | Posttest |
|---|---|---|---|---|---|
| 1 | 71 | 74 | 11 | 20 | 51 |
| 2 | 49 | 65 | 12 | 28 | 46 |
| 3 | 17 | 66 | 13 | 38 | 56 |
| 4 | 34 | 56 | 14 | 71 | 69 |
| 5 | 19 | 47 | 15 | 3 | 20 |
| 6 | 59 | 70 | 16 | 7 | 28 |
| 7 | 22 | 51 | 17 | 1 | 28 |
| 8 | 16 | 45 | 18 | 17 | 54 |
| 9 | 31 | 61 | 19 | 30 | 61 |
| 10 | 53 | 63 | 20 | 19 | 57 |

## Summary

In summary, no statistically significant differences were found between the visual and auditory groups when evaluating recall and transfer tasks for the presence of the modality principle. Participants in the visual group did have a larger mean on recall, transfer, and total scores but the difference between the two groups was very small especially taking standard deviations into account.

Upon consideration of reading levels, there was a lack of interaction between reading levels, mode of presentation, and performance on recall and transfer activities. Statistical significance was found for reading levels on recall and transfer assessments, but without taking method of instruction into consideration. The researcher found that low-level readers had higher scores on average on recall tasks in the audio condition but lower means on transfer tasks in the same condition. Medium-level and high-level readers showed a larger amount of positive change in the visual condition than the audio condition for recall and transfer activities.

# CHAPTER V
# SUMMARY, LIMITATIONS, DISCUSSION, AND IMPLICATIONS

The purpose of this experimental study was to examine two different multimedia instructional approaches to investigate which condition offers beneficial learning outcomes through recall and transfer assessments during a multimedia lesson on different types of energy in a fourth-grade classroom. This chapter includes the following sections: a summary of the study along with a discussion of the findings that emerged from this investigation. Specifically, a summary of the study and findings, conclusions, and implications for research and practice are presented.

## Summary of Study

The global emergence of technology has placed an importance on the use of instructional techniques and devices that incorporate technology in the elementary-school classroom. These instructional devices and approaches include computers and multimedia presentations that use images, text, and audio. The rapid progress and growth of technology has made it possible for more and more people to start creating and distributing multimedia materials with greater ease and at less cost, prompting the use of multimedia in the classroom (Samaras, Giouvanakis, Bousiou, & Trabanis, 2006). Now that these devices have been placed in the classroom, teachers can investigate the most effective ways to deliver instruction using technology.

Using older students in a variety of multimedia studies, researchers have attempted to identify how different instructional methods using multimedia prime cognitive processing during learning that results in meaningful learning (Schmidt-

Wiegand et al., 2010; Segers et al., 2008). An often-used approach to attempt to attain meaningful learning involves the use of words and pictures in a presentation format (Moreno, 2006; Witteman & Segers, 2010). More specifically, researchers have studied the learning effects of use of pictures and spoken words. Referred to as the modality principle, this instructional format has been the focus of a number of studies (Leahy & Sweller, 2011; Schmidt-Wiegand et al., 2010). Researchers who have studied this approach with older students as participants have produced results that show that this form of presentation with visuals and audio may contribute to better performance on recall and transfer tasks (Ginns, 2005).

Although a large amount of research has been completed on the modality principle using older students as participants, less is known about the possible effects of that modality principle with regard to instruction for elementary-school students. This study set out to add to the limited research previously completed on elementary-aged students (Leahy & Sweller, 2011; Witteman & Segers, 2010).

The purpose of this study was to examine two different multimedia instructional approaches to investigate which condition offered beneficial learning outcomes through recall and transfer assessments during a lesson on different types of energy in three fourth-grade classrooms. The independent variable was method of instruction including visuals accompanied by written text and visuals accompanied by identical information presented in audio form. The dependent variable was student performance on a recall and transfer assessment. Portions of the study were modeled after previous studies using older students as participants by attempting to expand working memory by using both audio and visual processors during a lesson (Leahy & Sweller, 2011; Moreno & Mayer, 2002), in order to learn if previous results using the modality principle with older students would transfer to younger students.

This study is unique because students' reading levels based on on a previous measure using comprehension scores were used to investigate the modality principle. An area of interest included how students with varying reading levels performed on a recall and transfer assessment when presented with an audio or visual presentation. A limited amount of research that has focused on the modality principle has included reading-comprehension levels as an independent variable (Scheiter et al., 2014; Witteman & Segers, 2010). If a possible relationship does exist between reading-comprehension levels and instructional condition, teachers may be able to make more informed decisions when choosing instructional delivery methods for different groups of students.

The instructional lesson was based on the forms of energy within the subject area of science, due to the recent research on the importance of understanding scientific concepts and cultivating a curiosity for science at a young age. Recently, the National Research Council (NRC, 2012) indicated that the elementary-school years are an integral time for capturing and sustaining student interest in science. The combination of scientific concepts being presented with multimedia may invoke more interest for students who are not motivated or not interested particularly in this subject area at a young age.

For these reasons, a study was completed that was guided by the following research questions.

1. When fourth-grade students are presented with visuals accompanied with audio instruction, to what extent does their performance on recall tasks compare with those fourth-grade students who are instructed with visuals and written text?
2. When fourth-grade students are presented with visuals accompanied with audio instruction, to what extent does their performance on transfer tasks compare with those fourth-grade students who are instructed with visuals and written text?
3. How do students with varying reading levels perform on recall and transfer tasks after being given audio or visual instruction?
4. What is the interaction effect between the modality principle and reading-comprehension levels tested on recall and transfer tasks?

In order to conduct a multimedia study using elementary-school students as participants similar to studies already completed with middle-school and high-school students, careful consideration was made in developing instruction with regard to the young age of the students. The sample consisted of 74 fourth graders in three schools located within a 5-mile radius. A 20-minute instructional unit on the forms of energy was conducted with one version of the instruction including visuals, animations, and written text and with the other version containing identical visuals, animations, and spoken words. Readability for the lesson was established at the 4.2 reading level because instruction was presented in October of the fourth-grade year. A 20-question pretest and posttest was developed and included recall and transfer questions.

Data were analyzed in accordance with the research questions. A two-way analysis of variance was used in order to investigate all research questions. For the first two research questions, a comparison of change from pretest to posttest scores provided information on possible differences in groups that received visuals with visual text in comparison with visuals and audio for recall and transfer questions. The two-way analysis of variance with instructional approaches and reading level as independent variables and differences between pretest and posttest scores as dependent variables also supplied information regarding performance related to reading levels for research questions three and four.

## Summary of Findings

When the frequencies for each question were examined without looking at conditions, results indicated that students showed growth for each question except for question number 14. For research questions one and two, comparisons were made between the visual and auditory groups with regard to performance on recall and transfer tasks. On recall tasks, students in the visual condition (Mv=9.08) scored higher on average than students in the audio condition (Ma=8.32). On transfer measures, students in the visual condition had a higher mean (Mv=10.22) than students in the audio condition (Ma=9.68). Boxplots in Figures 3 and 4 show more students in the audio condition scoring above the median than students in the visual condition.

For research questions three and four, the researcher investigated how groups with varying reading levels performed on recall and transfer tasks and the specific interactions that were or were not evident between reading levels, mode of presentation, and performance on recall and transfer tasks. The only area where statistical significance was found was between reading levels on recall and transfer tasks without taking method of instruction into consideration.

One month before the pretest, students took a measure of reading comprehension on the IOWA test of basic skills. Students in the visual and audio conditions means were 60.70 and 61.81, respectively demonstrating a minimal difference between the groups before analysis. No statistically significant results were found but trends can be found in the data. Low-level readers scored better on average in the auditory condition than the visual condition, whereas high-level readers scored higher on average in the visual condition than the auditory condition on recall tasks. On transfer tasks, however, low-level readers made more gains in the visual condition than the auditory condition when looking at group means.

**Limitations**

A number of limitations existed as this study took place. Statistical power was an issue for this study. The small numbers related to the number of participants when examining data point to little power for the interaction between variables.

Also related to the division of reading groups is the uncertainty related to whether or not students were placed correctly into groups that were deemed as low, medium, and high. Students who scored in the $34^{th}$ percentile or lower were put in the low-level group, students who scored in the $35^{th}$ to $67^{th}$ percentile were medium-level group, and students who scored in the $68^{th}$ percentile and higher were placed in the high-level group. The researcher placed them in these groups based on standard deviations above and below the mean. Students near the cut-off percentiles may have been placed in a different level depending on their effort or standardized scores for the entire population that took the test in the year of the study.

The population used for this study was not as diverse as possible. All students were members of schools that require families to pay school tuition. Also, no English as a second language students were included in this study because no ESL students were members of the participating classrooms.

The internal consistency reliability of the assessment is also a concern. There was a lack of consistency in student test scores. The reliability for the pretest and posttest was very low. When one question was omitted from the analysis, the reliability estimate increased but a test with better reliability would have contributed to more reliable results.

Instruction and testing took place in October, only one month and a half after school resumed from summer break suggesting that students may not be recovered completely from the break. The IOWA test administration occurred even earlier, in the third week of September. The amount of students who qualified for specific reading levels may had been different if the test had been administrated later in the school year. Some students may have scored lower on the previous measure due to the long summer break. Participants in this sample were young in comparison with other studies that have focused on the modality principle. Often, younger students can be unpredictable and inconsistent with answers that they supply on assessments. These inconsistencies may have affected the testing results.

The duration of the instructional unit was very short. Although students at the fourth-grade age may not have the attention span to be subject to lengthy lessons, the instruction may have been too short to get accurate assessment results because motivation for any particular student may be different from day to day and lesson to lesson. Also, because the pretest and posttest were given only a week apart, it may have been difficult to assess change in performance from the pretest to posttest. Student attitude and effort on any one particular day can vary, especially at such a young age.

The instructional lesson was designed by the researcher who is a teacher. The tendency of teachers to relay important information in ways that students understand may have surfaced during the lesson. For example, key words were repeated in the lesson in order to attempt to maximize understanding. This approach may have benefitted both instructional groups, negating possible differences on retention and transfer outcomes.

Students were informed that their grade in science would not be affected by the results of their pretests and posttests. Knowing that this lesson and their tests would not be a part of their grade may have contributed to a lack of motivation to do their best on the assessments, contributing to less reliable results on the pretests and posttests.

Students received instruction in two groups immediately after one another. No contact was made between students but their treatments were given at different times. Pretests were administered by each homeroom teacher. It may be possible that different teachers had different attitudes for the pretest even though they were trained on what to say and the directions to give before the pretest was administered.

The instructional material provided in the lesson on energy is part of the prescribed curriculum but different students have different levels of motivation when completing tests. It is possible that some students may not put forth the same effort on their test as other students or put forth a different amount of effort depending on the particular day. Also, determining whether students actually read the slides or were focused on listening to the material was very difficult for the researcher to determine. Although this may be the hope, these outcomes were not guaranteed.

Due to difficulty converting the instructional module on two of the schools' devices, instruction at these schools was completed in small groups of four or five depending on how many devices were available at each school. Though instruction was completed before any major breaks, such as recess or lunch, and teachers were instructed to watch for and discourage any communication between students, all students in each experimental group did not complete the instructional module at the same time.

All participants in this study were members of Roman Catholic schools in an archdiocese. Although the students are supplied with a curriculum that is similar to that of public schools, it is not identical. For this reason, the population used for the study may not be representative of the general population including public-school students.

## Discussion of Findings

Results of this study did not support the modality effect. Instead, results for both instructional groups were very similar with the visual group scoring a higher mean average than the auditory group on recall and transfer tasks. A larger statistically significant difference between these two groups in this direction would point to a reverse modality effect that has been found in a number of studies that have used a multimedia approach (Crooks et al., 2012; Tabbers et al., 2004; Witteman & Segers, 2010). As referenced in the literature review, the modality effect has surfaced in certain situations and the reverse modality effect has done the same, depending on the conditions of the study. A number of instances can help explain why the modality effect may not have been found in this study. Possible reasons for a reverse modality effect or results in which the two groups scored the same or almost the same are explained below.

Overall, students made large improvements from the pretest to the posttest without taking treatment groups or reading levels into consideration showing that learning did take place during the lesson. When looking at overall frequencies for each question, every question except for one showed a large number of students answering correctly on the posttest after they had gotten the question incorrect on the pretest.

Specifically, the visual group did have a higher mean than the audio group on recall and transfer tasks on the posttest without considering reading levels but the difference was very small, especially taking a large standard deviation (3.16) into account.

Participants had 55 seconds to study each slide in the instructional unit. Although the lesson was not user-paced, which can suggest negation of the modality effect (Tabbers et al., 2004), students in the visual condition still had an ample amount of time to reread information presented on the screen, whereas students in the audio condition were unable to do this almost replicating the time that would be available to participants during a user-paced study. Mayer (2001) suggested that the modality effect is strongest when words and pictures are presented at a fast pace with no opportunity to replay the presentation. Also, numerous studies have shown that when students are given the power to regulate the timing of an instructional module, the possible positive effects of the modality principle may be negated (Leahy & Sweller, 2011; Mann et al., 2002; Savoji et al., 2011). Crooks et al. (2012) suggested that learners may benefit from written text when perceptual load is low and participants have time to apply text-processing strategies. In order for all readers to have the time to read the text on-screen for this study, the time for each slide was extensive allowing participants in the text condition to reread while participants in the audio condition had to memorize the material. Students in the visual condition could see the material for duration of the time that the slide was on the screen and students in the audio condition could only hear the information once so it is possible that that students in the visual condition had more of an opportunity to retain the material.

As Leahy and Sweller (2011) hypothesized, written information is permanent, whereas spoken information is transient, and this difference may contribute to a lack of appearance of the modality principle. Because of this transiency, there may be no point to presenting lengthy or complex information using audio. The issue of complexity or element interactivity also should be mentioned at this point. Although the material in the lesson was new to the participants due to the idea that most students had no previous instruction or experience with the forms of energy, there were a number of words that were repeated in order to relay the necessary information on the forms of energy. For example, due to the importance of communicating the meaning of kinetic energy, the word movement was used three times during the lesson. It may be possible that the modality effect was negated because both groups processed the information successfully because certain aspects of the lesson were repeated in various slides.

Tindall-Ford et al. (1997) suggested that the modality principle would be negated if material is too simple due to the assumption that most students would understand the material without any scaffolding or accommodations due to its simplicity. As students are instructed in the lower grades, the amount of element interactivity may be limited. It is possible that due to the simplicity of information, statistically significant differences between visual and audio conditions may not exist.

Related to the issue of simplicity is the fact that a large number of studies completed on the modality principle that have found evidence for the modality principle have been focused on instructional material that teaches steps in an actual process (Mayer & Moreno, 1998; O'Neil et al., 2000). Had this study focused on complex material that displayed the steps in an actual larger process or system, modality effects may have been witnessed. Examples of processes that researchers have used have been lightning formation, how a car's braking system works, and the human respiratory system. This type of instruction that communicates many steps of a process does not lend itself well to participants at this age group because these students are often taught concepts in simpler form and in less steps.

When differences in the performances of different reading groups were studied, the results were not statistically significant as in the study by Scheiter et al. (2014). Low-level readers would be predicted to perform better on recall and transfer tasks if they were in the auditory condition because they would not have to read the material. Although low-level learners in the auditory condition performed marginally better on average, the opposite effect was found for transfer questions. Low-level readers in the auditory condition on average performed below low-level students in the text condition for transfer questions. For transfer questions, students were allowed to think more logically and given the opportunity to supply answers outside of what was taught directly. Students may have been able to answer these questions from their own life experiences or education outside of what is directly taught in school. This opportunity may explain why means on transfer questions were so similar for both groups.

Sheiter et al. (2014) suggested that low-literacy learners have problems acquiring knowledge from a transient multimedia presentation because spoken text may be difficult for these learners because unlike written text it does not allow for a processing that can be adapted to their level of understanding (Schuler et al., 2013). Conversely, low-level readers who received written text can slow down, read through complex information repeatedly, or skip irrelevant passages. When total change scores were examined with boxplots, however, the range of scores for low-level readers in the visual condition averaged between a three-point and five-point improvement. Students in the auditory condition had a much wider range of change scores ranging from zero points to nine points suggesting that some students in this condition may have benefitted from the auditory presentation more than others.

Also, it is possible that because the lesson was established at the 4.2 reading level, the majority of students did not have trouble reading and comprehending the words, therefore eliminating the benefit of receiving instruction in an auditory condition. The benefit that may have originally existed for low-level readers would disappear if they had no difficulty reading the material.

The importance of examining the outcomes of reading groups without comparison is important. Researchers have noted that high-achieving learners may perform well on recall and transfer activities regardless of the mode of delivery. So, the importance of examining the performance of low-achieving readers without comparing them to high achieving learners needs to be done. The high-level readers in this study had means that were higher than low-level and medium-level readers on recall and transfer tasks.

## Implications for Research

A number of implications for future research can be mentioned after the completion of this study. More research is needed using participants from the fourth-grade age or younger. Adding to the research base with participants of this age group can help teachers decide which instructional technique offers the best learning outcomes for their particular students. In addition, most research on the modality principle has been completed in laboratory settings (Brunken et al., 2002; Tabbers et al., 2004). A serious criticism of most research on the modality principle is that it was not based on multimedia instruction in authentic classroom environments such as K-12 school students learning school material in their classroom (Harskamp, Mayer, & Suhre, 2007). Studies that focus on elementary-school participants in authentic classrooms contribute to research and practices that can be relayed into the classroom immediately.

Most studies that have focused on the modality principle involve assessing students immediately after instruction but delayed assessments are often not part of research studies. If the goal of instruction is to encourage students to retain information over long periods of time, future research should be completed with delayed assessments given in accordance with immediate assessments. In one of the few studies that focused on delayed assessments as well as immediate assessments, Witteman and Segers (2010) found a modality effect for lightning lessons when sixth-grade students received an immediate assessment but a reverse modality effect when students received a delayed assessment on the same material. Also, Segers et al. (2008) found modality effects for fifth-grade students immediately after learning, but the effects disappeared after one week for retention measures. For transfer questions, a reverse modality effect was found when students were assessed one week later. Schweppe and Rummer (2012) found similar effects when one group in their study was assessed immediately after instruction and the other group was assessed one week later. The differences in the studies above with regard to participant age, different types of text and subject matter, and length of tests also point to a need for more studies that use similar designs in order to obtain generalizable results for particular populations and lesson types.

The addition of another instructional approach that includes the combination of visuals, written text, and audio also should be considered as an area of future research. Previous research has found that this instructional approach may contribute to cognitive overload due to the variety of instructional methods being used (Mousavi, Low & Sweller 1995). This research, however, has not been completed on students younger than sixth grade. Students in the younger elementary grades may benefit from this instructional approach.

Researchers of future studies should also consider the implications of using English as a second language students. It is possible that students who are less familiar with the English language may benefit from instruction with pictures with audio or text.

The type of pictures that are used during a multimedia lesson also should be an area of future research. For this study, a combination of animations and still pictures were included in the instructional material. It is possible that either type of picture may be more beneficial for teachers to use in order to improve learning outcomes. A study that compares an instructional unit using animations and an instructional unit using still pictures may add to the research on instructional-design approaches.

The time allotted for each slide in an instructor-paced lesson also should be given attention by researchers. For this study, the time for each slide was reduced from 60 second to 55 seconds after the researcher realized that the participants had too much time for each slide. Upon observing participant behavior in the pilot study, the researcher noticed that students were looking away from the computer screen after reading or listening to the words. Research conducted on what students do or think about with this extra time could allow teachers and instructional designers to decide whether or not the extra time is necessary for processing or whether students should just be given the minimal time to read or listen to the slide material before moving on to the next one.

Another area in need of future research is exploring a measure of cognitive load during learning. If there was a means of knowing when a learner becomes overloaded with material or which types of learners are overloaded at a quicker pace, teachers may be able to individualize lessons more appropriately. Particularly, gauging cognitive load experienced by learners, cognitive demands of instructional materials and cognitive resources available to individual learners should be studied (Mayer & Moreno, 2003). Studies that employ a direct and reliable measure of cognitive load have yet to be found. Often, transfer test measures are used as an indirect measure with high transfer test performance as an indication of less extraneous processing during learning (de Jong, 2010). The uncertainty of this procedure can suggest the need for a more direct measure of cognitive load.

Student perception of technological tools should also be an area of future research. Surveys at the end of instructional lessons using visual, text, audio, or both can offer valuable insights in areas related to student motivation. If students enjoy lessons and the way in which lessons are delivered, they may be more motivated to engage in the lesson and perform well on assessment tasks. So asking them about which methods they enjoy the most can play a role in the techniques that teachers use when preparing lessons. Included in this survey, could be student perceptions of animations versus still pictures. Student thoughts on which type of graphic they prefer or which they feel they learn from can play a valuable role in teacher-constructed lessons.

A large amount of research has been completed on the modality principle in recent years. Now that researchers know that it can be an effective means of instruction, more studies on the most common times that the modality principal is evident are needed. Additional studies on the modality principle can add to the existing research on boundary conditions such as pace of presentation, complexity of material, and element interactivity.

## Implications for Practice

Although the results of this study were not statistically significant, there are some practical considerations that can be derived from the results. The study of cognitive-load theory and the modality principle can guide instructors to design their lessons in ways that foster meaningful learning. Instructional design that proceeds without reference to human cognition is likely to be random in its effectiveness (Paas & Sweller, 2014). So whether teachers are choosing which lessons to use or designing lessons in a certain subject area, they need to be educated on the best practices that relate to multimedia. Multimedia messages deliver information to the learner, but not all of these messages are conveyed effectively so it is the responsibility of the instructor to be educated on the best practices related to multimedia instruction.

The process of designing multimedia lessons can be time consuming for teachers. Much time can be spent on choosing still visuals or animations. The use of animations may take considerably more time than the use of still visuals when designing lessons. It can be more practical for teachers to design lessons using still visuals because they are more accessible and take less time to include in the instructional material. Teachers and instructional designers should also keep up-to-date with research that may test still visuals against animations to determine which approach results in more positive learning outcomes.

Related to the difficulty and time used in constructing or choosing multimedia lesson is the importance of a collaborative approach in accomplishing the feat of designing and choosing quality lessons. Teachers should be encouraged to share their lessons through some system that promotes collaboration. A number of teachers may not be familiar with designing multimedia-lessons and if they were able to access and use these lessons, they may be able to offer a new quality teaching approach to their students. Although this approach may not be offered through an online service, teachers familiar with multimedia design and instruction should be encouraged to share their ideas with others.

Because the results of this study did not suggest a modality effect, it is difficult to provide the recommendation to spend the extra time designing a lesson that consists of pictures, animations, and audio. Instead, participants who receive written text for this type of lesson rather than audio may perform better or just as well on recall and transfer tasks. Students who are low-level readers did not have much of an advantage when receiving information through audio. In fact, these students in the written condition scored higher, on average, on transfer tasks than those in the audio condition. The practice of the use of visuals during instruction has been supported by current research (Mayer, 2009). This practice, in accordance with written words may produce better, if not at least the same results for students on recall and transfer tasks. It is recommended that the use of written text and visuals may benefit students as much, if not more than the use of visuals with audio for this age group.

## Conclusions

A number of conclusions can be made from the results of this study. First, although statistically significant results were not found for the modality principle, its possible existence should not be dismissed. Without a large amount of research completed on this population, it is difficult to conclude whether or not the modality principle would be found for this particular age group. Additional studies may contribute to this conclusion. It is possible that a lesson constructed like the one for this study may contribute to a reverse modality effect for students at this age level. Because students at this level are often taught simpler material, the simplicity of information may negate the modality effect that has been found for more difficult material in previous studies.

In recent years, a large number of studies have failed to find the modality effect (Crooks et al., 2012; Leahy & Sweller, 2011; Schuler et al. 2012). This difficulty in finding the modality effect should encourage researchers to define and explain boundary conditions such as pace of presentation and element interactivity that may impede the modality principle from being found.

Based on the results of this study, designing instruction with visuals in conjunction with auditory text may not contribute to a modality effect. Statistically significant results were not found in favor of a modality effect. Presenting information with visuals and auditory words without written text may aid struggling readers marginally with recall but not necessarily transfer tasks. Therefore, results of the study suggest that supplying students with presentations with visuals and written text or visuals and audio may result in similar learning outcomes. Awareness of these outcomes can give teachers an opportunity to choose either method of delivery without negative consequences for their students.

**References**

American Psychological Association. (2010). Ethical Principles and Code of Conduct for Psychologists 2010 Amendments. *The American Psychologist, 65,* 8.02 doi: 10.1037/a0020168

Ardac, D., & Akaygun, S. (2004). Effectiveness of multimedia-based instruction that emphasizes molecular representations on students' understanding of chemical change. *Journal of Research in Science Teaching, 41*, 317-337.

Baddeley, A.D. (1986). *Working memory*. Oxford, UK: Oxford University Press.

Balanskat, A., Blamire, R., & Kafola, S. (2006). *A review of studies of ICT impact on schools in Europe.* (ERIC Report ED 479843)

Barnett, H. (2003). Investing in technology: *The payoff of student learning.* ERIC/IT Digest. Washington, DC: Office of Educational Research and Improvement.

Bektas, M. (2013). An examination of the elementary school teachers preferred teaching methods and instructional technologies in terms of various variables in life study lesson*. International Online Journal of Educational Sciences, 5*, 551-561.

Benson, A., & Blackman, D. (2003). Can research methods ever be interesting? *Active Learning in Higher Education*, *4*, 39-55. doi:10.1177/1469787403004001004

Blanchard, J., Stock, W., & Marshall, J. (1999). Meta-analysis of research on a multimedia elementary school curriculum using personal and video game computers. *Perceptual and Motor Skills, 88*, 329-336.

Blank, R. (2012). Science instructional time is declining in elementary schools: What are the implications for student achievement and closing the gap? *Science Education, 97*, 830-847.

Brunken, R., Steinbacher, S., Plass, J., & Leutner, D. (2002). Assessment of cognitive load in multimedia learning using dual-task methodology. *Experimental Psychology, 49*, 109-119. doi: 10.1027//1618-3169.49.2.109

Butcher, K. (2014). The multimedia principle. In Mayer, R. (Ed.) *The Cambridge Handbook of Multimedia Learning* 2nd ed. (pp. 72-103). New York, NY: Cambridge University Press.

Chandler, P., & Sweller, J. (1992). The split-attention effect as a factor in the design of instruction. *British Journal of Educational Psychology, 62*, 233-246. doi: 10.1111/j.2044-8279.1992.tb01017.x

Chang, H.Y., Quintana, C., & Krajcik, J.S. (2010). The impact of designing and evaluating molecular animations on how well middle school students understand the particulate nature of matter. *Science Education, 94*, 73-94. doi: 10.1002/sce.20352

Cheung, A., & Slavin, R. (2012). How features of educational technology applications affect students' reading outcomes: A meta-analysis. *Educational Research Review, 7*, 198-215. doi: 10.1016/j.edurev.201205.002

Choudhary, G., & Bhardwaj, S. (2011). ICT and professional development of teachers. *International Journal of Educational and Allied Sciences, 3*(2), 49-52.

Clark, R., & Mayer, R. (2008). *E learning and the science of instruction*. San Francisco, CA: John Wiley & Sons Inc.

Clark, R., Nguyen, F., & Sweller, J. (2005). *Efficiency in learning: Evidence-based guidelines to manage cognitive load*. San Francisco, CA: John Wiley & Sons Inc.

Cloonan, A. (2007). *Professional learning of teachers: a case study of multiliteracies teaching in the early years of schooling* (Unpublished thesis). Royal Melbourne Institute of Technology: Melbourne, Australia.

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences*, *24*, 87-114.

Crawford, B.A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching, 44*, 613-642.

Crooks, S., Cheon, J., Inan, F., Ari, F., & Flores, R. (2012). Modality and cueing in multimedia learning: Examining cognitive and perceptual explanations for the modality effect. *Computers in Human Behavior, 28*, 1063-1071. doi: 10.1016/j.chb.2012.01.010

Cviko, A., McKenney, S., & Voogt, J. (2013). Teacher roles in designing technology-rich learning activities for early literacy: A cross-case analysis. *Computers and Education, 72*, 68-79. doi: 10.1016/j.compedu.2013.10.014

de Jong, T. (2010). Cognitive load theory, educational research, and instructional design: Some food for thought. *Instructional Science, 38*, 105-134. doi: 10.1007/s11251-009-9110-0

Diakidoy, I., Stylianou, P., Karefillidou, C., & Papageorgiou, P. (2005). The relationship between listening and reading comprehension of different types of text at increasing grade levels. *Reading Psychology, 26*, 55-80. doi: 10.1080/02702710590910584

Driscoll, M.P. (2005). *Psychology of learning for instruction.* Tallahassee, FL: Florida State University.

Dorph, R., Shields, P., Tiffany-Morales, J., Harty, A., & McCaffrey, T. (2011). *High hopes-few opportunities: The status of elementary science education in California.* Sacramento, CA: The Center for the Teaching and Learning at WestEd.

Eccles, J.S., Wigfield, A. & Schiefele, U. (1998). Motivation. In N. Eisenberg (Ed.), *Handbook of child psychology* (Vol. 3, 5th ed, pp.1017-1095). New York, NY: Wiley & Sons.

Ercan, O. (2014). The effects of multimedia learning material on students' academic achievement and attitudes towards science courses. *Journal of Baltic Science Education, 13*, 608-621.

Ferreira, C., Baptista, M., & Arroio, A. (2013). Teachers' pedagogical strategies for integrating multimedia tools in science teaching. *Journal of Baltic Science Education, 12*, 509-524.

Flores, R., Coward, F., & Crooks, S. (2010). Examining the influence of gender on the modality effect. *Journal of Educational Technology Systems, 39*(1), 87-103. doi: 10.2190/ET.39.1.g

Ginns, P. (2005). Meta-analysis of the modality effect. *Learning and Instruction*, *15,* 313-331.

Ginns, P., Marin, A.J., & Marsh, H.M. (2013). Designing instructional text for conversational style: A meta-analysis. *Educational Psychology Review, 25*, 445-472.

Harskamp, E., Mayer, R., & Suhre, C. (2007). Does the modality principle for multimedia learning apply to science classrooms? *Learning and Instruction, 17*, 465-477. doi: 10.1016/j.learninstruc.2007.09.010

Hutinger, P., Bell, C., Daytner, G., & Johanson, J. (2006). Establishing and maintaining an early childhood emergent literacy technology curriculum. *Journal of Special Education Technology, 21*(4), 39-54.

Jamet, E. (2013). An eye-tracking study of cueing effects in multimedia learning. *Computers in Human Behavior, 32*, 47-53. doi: 10.1016/j.chb.2013.11.013

Jonassen, D. (2000). Transforming learning with technology: Beyond modernism and post-modernism or whoever controls the technology creates the reality. *Educational Technology, 40*(2), 21-25.

Kalantzis, M., & Cope, B. (2010). The teacher as designer: Pedagogy in the new media age. *Journal of E-Learning and Digital Media, 7*, 200-222. doi: 10.2304/elea.2010.7.3.200

Kalyuga, S. (2011). Cognitive load theory: How many types of load does it really need? *Educational Psychology Review, 23(1)*, 1-19. doi: 10.1007/s10648-010-9150-7

Kalyuga, S., Chandler, P., & Sweller, J. (2000). Incorporating learner experience into the design of multimedia instruction. *Journal of Educational Psychology*, *92*, 126-136.

Kirik, O. (2013). Science teaching efficacy of preservice elementary teachers: examination of the multiple factors reported as influential. *Research in Science Education, 43,* 2497-2515. doi: 10.1007/s11165-013-9357-y

Koehler, M.J., & Mishra, P. (2005). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research, 32*(2), 131-152. doi: 10.2190/0EW7-01WB-BKHL-QDYV

Kozma, R., & McGhee, R. (2003). ICT and innovative classroom practices. In R. Kozma (Ed.), *Technology, innovation, and educational change: A global Perspective* (pp. 43-80). Eugene, OR: International Society for Educational Technology.

Leahy, W., & Sweller, J. (2011). Cognitive load theory, modality of presentation, and the transient information effect. *Applied Cognitive Psychology, 25*, 943-951. doi: 10.1002/acp. 1787

Lui, Y. (2012). Effects of integrating multimedia into the third grade mathematics curriculum to improve student learning. *Journal of Educational Technology Systems, 40,* 251-271.

MacDonald, W. (2003). The impact of job demands and workload on stress and fatigue. *Australian Psychologist*, *36*,102-117. doi: 10.1080/000500 10001707107

Mann, B. (1995). Focusing attention with temporal sound. *Journal of Research on Computing Education, 27*, 402-424. doi: 10.1080/08886504.1995.10782142

Mann, B., Newhouse, P., Pagram, J., Campbell, A., & Schulz, H. (2002). A comparison of temporal speech and text cueing in educational multimedia. *Journal of Computer Assisted Learning, 18,* 296-308.

Mayer, R. (1997). Multimedia learning: Are we asking the right questions? *Educational Psychologist, 32*(1), 1-19. doi: 10.1207/s15326985ep3201_1

Mayer, R. (2006). Ten research based principles of multimedia learning. In F. O'Neil & R. Perez (Eds.), *Web-based learning: Theory, research and practice* (pp. 371-390). Mahwah, NJ: Lawrence Erlbaum Associates.

Mayer, R. (2008). Applying the science of learning: evidence based principles for the design of multimedia instruction. *American Psychologist, 63*, 757-769. doi: 10.1037/003-066x.63.8.760

Mayer, R. (2009). *Multimedia learning*. New York, NY: Cambridge University Press.

Mayer, R. (2014). *The Cambridge Handbook of Multimedia Learning*. New York, NY: Cambridge University Press.

Mayer, R.E., & Chandler, P. (2001). When learning is just a click away: Does simple user interaction foster deeper understanding of multimedia messages? *Journal of Educational Psychology, 93,* 390-397. doi: 10.1037/0022-0663.93.2.390

Mayer, R., Fennell, S., Farmer, L., & Campbell, J. (2004). A personalization effect in multimedia learning: Students learn better when words are in conversational style rather than formal style. *Journal of Educational Psychology, 96,* 389-395. doi: 10.1037/0022-0663.96.2.389

Mayer, R., Heiser, J., & Lonn, S. (2001). Cognitive restraints on multimedia learning: When presenting more material results in less understanding. *Journal of Educational Psychology, 93*(1), 187-198. doi: 10.1037/0022-0663.93.1.187

Mayer, R., & Moreno, R. (1998). A split attention effect in multimedia learning: evidence for dual processing systems in working memory. *Journal of Educational Psychology, 90,* 312-320. doi: 10.1037/00222-0663.90.2.312

Mayer, R., & Moreno, R. (2002). Aids to computer-based multimedia learning. *Learning and Instruction, 12*, 107-119.

Mayer, R., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist, 38*(1), 43-52.

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

McNamara, D., & Magliano, J. (2009). Towards a comprehensive model of comprehension. *The Psychology of Learning and Motivation, 51*, 297-384. doi: 10.1016/S0079-7421(09)51009-2

Miller, G. (1994). The magical number seven plus or minus two: Some limits on our capacity for processing information*. Psychological Review*, 101, 343-352. doi: 10.1037/0033-295X.101.2.343

Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *The Teachers College Record, 108,* 1017-1054.

Moreno, R. (2006). Does the modality principle hold for different media? A test of the method- affects- learning hypothesis*. Journal of Computer Assisted Learning, 22,* 149-158.

Moreno, R., & Mayer, R. (2002). Animation as an aid to multimedia learning. *Educational Psychology Review, 14(*1), 87-99. doi:10.1023/A:101318461107d

Moreno, R. & Park, B. (2005). Cognitive load theory: Historical development and relation to other theories. In J. Plass, R. Moreno, & R. Brunken (Eds.), *Cognitive Load Theory* (pp. 9-22). New York, NY: Cambridge University Press.

Mousavi, S., Low, R., & Sweller, J. (1995). Reducing cognitive load by mixing auditory and visual presentation modes. *Journal of Educational Psychology, 87*, 319-334

National Council of Teachers of Mathematics. (2008). *Principles and Standards for School Mathematics*. Reston, VA: National Council of Teachers of Mathematics

National Research Council. (2012). *Framework for K- 12 science education.* Washington, DC: National Academy Press.

Nord, C., Roey, S., Perkins, S., Lyons, M., Lemanski, N., Schuknecht, J., & Brown, J. (2011). *America's high school graduates: Results of the NAEP high school transcript study.* Washington, DC: U.S. Department of Education, National Center for Education Statistics.

O'Neil, H.F., Mayer, R.E., Herl, H.E., Niemi, C., Olin, K., & Thurman, R.A. (2000). Instructional strategies for virtual aviation training environments. In H.F. O'Neil & D.H. Andrews (Eds.), *Aircrew training and assessment* (pp. 105-130). Mahwah, NJ: Lawrence Erlbaum.

Paas, F., Renkl, A., & Sweller, J. (2004). Cognitive load theory: Instructional implications of the interaction between information structures and cognitive architecture. *Instructional Science, 32*, 1-8.

Paas, F., & Sweller, J. (2014). Implications of cognitive load theory for multimedia *learning*, In R. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (2nd ed. pp. 27-42) New York, NY: Cambridge University Press.

Paivio, A. (1986). *Mental representations: A dual coding approach.* Oxford UK:Oxford University Press.

Penney, C.G. (1989). Modality effects in delayed free recall and recognition: Visual is better than auditory. T*he Quarterly Journal of Experimental Psychology, 41*, 455-470. doi: 10.1080/14640748908402376

Plass, J., Moreno, R., & Brunken, R. (2010). *Cognitive load theory*. New York, NY: Cambridge University Press.

Rozmiarek, D.J. (2000). *Learning from multimedia: An examination of the role of reading ability and working memory.* (Unpublished doctoral dissertation). University of Delaware, Newark, Delaware.

Rummer, R., Schweppe, J., Furstenberg, A., Zindler, A., & Scheiter, K. (2011). The perceptual basis of the modality effect in multimedia learning. *Journal of Experimental Psychology, 17*, 159-173. doi: 10.1037/a0023588

Samaras, H., Giouvanakis, T., Bousiou, D., & Tarabanis, K. (2006). Towards a new generation of multimedia learning research. *Association for the Advancement of Computing in Education Journal, 14*, 3-30

Savoji, A., Hassanabadi, H., & Fasihipour, Z. (2011). The modality effect in learner-paced multimedia learning. *Social and Behavioral Sciences, 30*, 1488-1493. doi: 10.1016/j.sbspro_2011.10.288

Scheiter, K., Schuler, A., Gerjets, P., Huk, T., & Hesse, F. (2014). Extending multimedia research: How do prerequisite knowledge and reading comprehension affect learning from text and pictures? *Computers in Human Behavior, 31*, 73-84. doi: 10.1016/j.chb.2013.09.022

Schmidt-Wiegand, F., Kohnert, A., & Glowalla, U. (2010). Explaining the modality and contiguity effects: New insights from investigating students' viewing behavior. *Applied Cognitive Psychology, 24*, 226-237. doi: 10.1016/j.learninstruc.2009.02.011

Schnotz, W. (2014). Integrated model of text and picture comprehension. In R.E Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (pp. 72-103). New York, NY: Cambridge University Press.

Schnotz, W., & Kulhavy, R. (1994). *Comprehension of graphics.* Amsterdam, Netherlands: North Holland.

Schnotz, W., Mengelkamp, C., Baadte, C., & Hauck, G. (2014). Focus of attention and choice of text modality in multimedia learning. *European Journal of Psychological Education, 29*, 483-501. doi: 10.1007/s10212-013-0209-y

Schuler, A., Scheiter, K.., Rummer, R., & Gerjets, P. (2012). Explaining the modality effect in multimedia learning: Is it due to a lack of temporal contiguity with written text and pictures? *Learning and Instruction, 22*, 92-102. doi: 10.1016/jlearninstruc.2011.08.001

Schuler, A., Scheiter, K., & van Genuchten, E. (2011). The role of working memory in multimedia instruction: Is working memory working during learning from text and pictures? *Educational Psychological Review, 23,* 389-411. doi: 10.1007/s10648-011-9168-5

Schweppe, J., & Rummer, R. (2016). Integrating written text and graphics as a desirable difficulty in long-term multimedia learning. *Computers in Human Behavior, 60,* 131-137. doi: 10.1016/j.chb.2016.02.035

Segers, E., Verhoeven, L., & Hulstijn-Hendrikse, N. (2008). Cognitive processes in children's multimedia text learning. *Applied Cognitive Psychology, 22*, 375-387. doi: 10.1002/acp.1413

Shilling, W. (1991). *Kindergarten learners constructing knowledge about literacy, Using conventional materials and computers.* (Unpublished dissertation). Hofstra University, New York, NY

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-23.

Sticht, T. G., Beck, L.J., Hauke, R.N., Kleinman, G.M., & James, J.H. (1974*). Auding and reading: A developmental model.* Alexandria, VA: Human Resources Research Organization.

Sweller, J. (1989). Cognitive technology: Some procedures for facilitating learning and problem solving in mathematics and science. *Journal of Educational Psychology, 81*, 457-456. doi: 10.1037/0022-0663.81.4.457

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction*, *4*, 295-312. doi: 10.1016/0959-4752(94)90003-5

Sweller, J. (2005). The redundancy principle in multimedia learning. In R.E Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (pp. 159-167). New York, NY: Cambridge University Press.

Sweller, J. (2010). Element interactivity and intrinsic, extraneous, and germane cognitive load. *Educational Psychology Review, 22*(2), 123-138. doi: 10.1007/s10648-010-9128-5

Sweller, J., & Chandler, P. (1994). Why some material is difficult to learn. *Cognition and Instruction, 12*, 185-233

Tabbers, H. (2002). *The modality of text in multimedia instructions: Refining the design guidelines.* DL Heerlen, Netherlands: Open University of the Netherlands.

Tabbers, H., Martens, R., & Merrienboer, J. (2004). Multimedia instructions and cognitive load theory: Effects of modality and cueing. *British Journal of Educational Psychology, 74*, 71-81. doi: 10.1348/000709904322848824

Tasci, G., & Soran, H. (2008). The effects of multimedia applications in cell division subject on the comprehension and application levels of learning achievement. *Hacettepe University Journal of Education, 34*, 233-243

Thrash, T., & Elliot, A. (2001). Delimiting and integrating achievement motive and goal constructs. In A. Efklides, J. Kuhl, & R. Sorrentino (Eds.), *Trends and prospects in motivation research.* (pp. 3-21) Boston, MA: Kluwer

Tindall-Ford, S., Chandler, P., & Sweller, J. (1997). When two sensory modes are better than one. *Journal of Experimental Psychology*: *Applied, 3,* 257-287. doi: 10.1037/076-898X.3.4.257

Van den Broek, P.W. (2010). Using texts in science education: Cognitive processes and knowledge representation. *Science*, *328*, 453-456. doi: 10.1126/science.1182594

Van Sommeren, M., Reimann, P., Boshuizen, H., & de Jong, T. (1998). *Learning with multiple representations.* Amsterdam, Netherlands: Pergamon.

Webb, M. (2005). Affordances of ICT in science learning: Implications for an integrated pedagogy. *International Journal of Science Education, 27*, 705-735. doi: 10.1126/science.1182594

Weiner, R. (1991). Computerized speech: A study of its effect on learning. *Technological Horizons in Education, 2*, 100-102.

Witteman, M.J., & Segers, E. (2010). The modality effect tested in children in a user paced multimedia environment. *Journal of Computer Assisted Learning, 26*, 132-142. doi: 10.1111/j.1365-2729.2009.00335.x

Appendixes

# Appendix A

## Consent Forms

Appendix A

Consent Forms

Dear

My name is Laura Sandoval and I am the second-grade teacher at .
Currently, I am a fifth-year doctoral student at the University of San Francisco in the Learning and Instruction program. As I prepare to conduct research in order to write my dissertation, I would like to ask for your consent to conduct this research.

My experimental research will take place in three fourth-grade classrooms at schools in the Archdiocese of San Francisco. A multimedia lesson on the forms of energy will be taught over one class period. Students will also be tested one week before, and immediately after instruction. A pilot study will be conducted in May of 2015. In October of 2015, the actual study will be conducted. Instructional content is in compliance with Archdiocesan and state standards. Your signature on the enclosed consent letter indicates you acknowledge and authorize research to be conducted on school grounds in the archdiocese with consent of the principals, fourth grade teachers, and the parents of the students. Please call or email me with any questions or concerns.

Laura Sandoval

Consent for Research

My signature below indicates that I acknowledge and authorize Laura Sandoval to conduct classroom research in three fourth- grade classrooms in the archdiocese. I am aware that the design of the study includes a multimedia lesson in the form of one treatment and a pre- and post-assessment. I am also aware that a pilot study will be conducted in one fourth-grade classroom during the 2014/2015 school year.

________________________________________

Name

________________________________________

Signature

As Superintendent, I have given Ms. Laura Sandoval permission to conduct her research in our school system. I have communicated with Ms. Sandoval and understand the scope of her research and how she will collect her data.

# STUDENT AND PARENTAL CONSENT FOR RESEARCH PARTICIPATION

**Purpose and Background**

Laura Sandoval, a doctoral candidate at the University of San Francisco, is conducting a pilot study on the effects of audio and visual delivery methods during a multimedia lesson. Your child is being asked to participate in this study because he or she is a student in the fourth-grade class.

**Procedures**

The procedures for this study will take place in the computer lab and fourth grade classroom. If you agree to allow your child to participate in this study, you are giving consent for the following pieces of data to be used in the researcher's data collection:

1) Your child's results on a pretest and posttest before and after a multimedia lesson on the forms of energy
2) Results of the IOWA Test of Basic Skills in reading comprehension.

**Risks and/or Discomforts**

It is unlikely that any of the items on the assessment will make your child feel uncomfortable. Every attempt will be made to keep your child's results confidential. No individual identities will be used in any reports or publications resulting from this pilot study.

**Benefits**

Your child will gain a deeper understanding of the content material that directly correlates with Archdiocesan and California State Standards.

**Costs**

There will be no cost to you or your child for participating in this pilot study.

**Payment/Reimbursement**

Neither you nor your child will be paid to participate in this study.

**Questions**

If you have questions or comments regarding this study, first contact the researcher, Laura Sandoval, by calling . If for some reason you do not wish to do so, you may contact the IRBPHS office by calling (415) 422-6091 or by writing to the IRBPHS, Counseling and Psychology Department, School of Education Building, University of San Francisco, 2130 Fulton Street, San Francisco, CA 94117-1080

**Consent**
Participation in this research is voluntary. Although your child is expected to participate in the classroom activities, allowing your child's test results to be used is completely voluntary.

If you agree to allow your child to participate, please keep one copy for your records and sign one copy and return it with your child as soon as possible.

Thank you,
Laura Sandoval
Doctoral Student, University of San Francisco

---

**STUDENT CONSENT FOR RESEARCH PARTICIPATION**

**CONSENT FORM**

_____________I agree to participate in this study

_____________I do not agree to participate in this study.

_____________________________________________________________________________
Student's signature Date

**PARENTAL CONSENT FOR RESEARCH PARTICIPATION**

**CONSENT FORM**

_____________I agree to allow my child to participate in this study.

_____________I do not allow my child to participate in this study.

_____________________________________________________________________________

Parent's signature

# TEACHER CONSENT FOR RESEARCH PARTICIPATION

**Purpose and Background**
Laura Sandoval, A doctoral candidate at the University of San Francisco, is conducting a pilot study on two multimedia instructional approaches. You are being selected as a teacher to participate in this study because of your position as a fourth grade teacher.

**Procedures**
The procedures for this pilot study will take place during your science period. By agreeing to participate in this study, you are asked to fulfill the following research components:

1. Administrating one pretest, one week before instruction, with recall and transfer questions. The pretest will take approximately 20 minutes.
2. Allowing access of half of your class for one thirty minute instructional session in the computer lab followed by the other half of the class The posttest will take place immediately after and will last approximately an additional 20 minutes.
3. Participation in a short training session

**Risks and/or Discomforts**
It is unlikely that you will be in an uncomfortable position. During the pretest, students may have difficulties and try to ask for help. In order to get a clear picture of student knowledge before instruction, assistance on actual test questions may not be given.

**Benefits**
There is no direct benefit to you for participating in this study. However, you may gain a more complete understanding of beneficial instructional approaches using multimedia.

**Costs**
There will be no cost to you for participating in this study.

**Payment/Reimbursement**
No monetary reimbursement will be given to you for participating in this study.

**Questions**
If you have questions or comments regarding this study, first contact the researcher, Laura Sandoval, by calling . If for some reason you do not wish to do so, you may contact the IRBPHS office by calling (415) 422-6091 or by writing to the IRBPHS, Counseling and Psychology Department, School of Education Building, University of San Francisco, 2130 Fulton Street, San Francisco, CA 94117-1080

**Consent**
Participation in this study is voluntary. If you agree to participate, please sign and return as soon as possible.

Thank you,
Laura Sandoval
Doctoral Student, University of San Francisco

**TEACHER CONSENT FOR RESEARCH PARTICIPATION CONSENT FORM**

___________ I agree to participate in this study.

___________ I do not agree to participate in this study.

______________________________________________________________________
Name                                                                Title/Position

______________________________________________________________________
Teacher's Signature                                                 Date

Dear

I am currently a doctoral student at the School of Education at the University of San Francisco. As part of my degree requirements, I will be conducting an experimental study on two multimedia presentation approaches.

To fulfill the study that will be conducted in October of 2015, I need your consent to include your fourth graders as participants in my study. First, a pretest will be given on the forms of energy and the various characteristics that make each one unique. A week later, students will view a multimedia lesson on these forms. Immediately following instruction, students will take a posttest on the content. Tests results will be compared to highlight any learning gains. In addition, scores on the IOWA Test of Basic Skills will be used as a variable in the area of reading. Again, student names will be kept confidential.

Participation in this study is entirely voluntary. The participants' identities will remain anonymous. The superintendent of schools has approved my request to conduct this research. Your signature on the enclosed consent letter indicates that you acknowledge and authorize research to be conducted on school grounds with the consent of fourth grade teachers, students, and parents. Please sign the attached consent form as soon as possible.

Sincerely,

Laura Sandoval
Doctoral Candidate
School of Education
University of San Francisco

Consent for Research

My signature below indicates that I authorize Laura Sandoval to conduct classroom research in the fourth grade classroom and computer lab. I am aware that the design of the study includes a multimedia presentation and a pretest and posttest. Test results will be collected and analyzed with the consent of students and parents.

________________________________________________________

Name Title/Position

________________________________________________________

Signature Date

# Appendix B

## Instructional Materials

# Appendix B

## Instructional Materials

## Pretest/ Posttest (Final Study)

Name_______________________________________________

Circle the letter of the correct answer.

1. Which of these is an example of energy?
    a) a boy playing soccer
    b) a chair in the kitchen
    c) books in a desk
    d) a pencil

2. Which of these is an example of sound energy?
    a) a bike in the backyard
    b) water in a bucket
    c) listening to your teacher read a story
    d) a person standing in an elevator

3. How many types of energy are there?
    a) 6
    b) 8
    c) 2
    d) 5

4. Which of these is a basic form of energy?

a) muscle energy

b) sound energy

c) wave energy

d) weather energy

5. A car waiting at a red light has which of these types of energy?

a) kinetic energy

b) potential energy

c) wave energy

d) light energy

6. What kind of energy is created by the sun?

a) kinetic energy

b) light energy

c) electrical energy

d) thermal energy

7. What is the energy of motion called?

a) potential energy

b) kinetic energy

c) chemical energy

d) thermal energy

8. What kind of energy is stored in an object?

a) kinetic energy

b) light energy

c) potential energy

d) thermal energy

9. A car in motion is an example of what kind of energy?

   a) light energy

   b) sound energy

   c) kinetic energy

   d) thermal energy

10. What kind of energy to plants use to make their food?

    a) light energy

    b) thermal energy

    c) kinetic energy

    d) electrical energy

11. Hamburgers cooking on a stove is an example of which kind of energy?

    a) thermal energy

    b) potential energy

    c) kinetic energy

    d) electrical energy

12. A flag blowing in the wind is showing which kind of energy?

    a) potential energy

    b) kinetic energy

    c) thermal energy

    d) light energy

13. A boy is holding a baseball in his hand. He is ready to throw it.

    What kind of energy does the ball have as it is sitting in his hand?

    a) electrical energy

    b) thermal energy

    c) kinetic energy

    d) potential energy

14. Name two things in your school or house that use electrical energy.

___

___

15. During a kickball game, a ball is kicked high in the air. Does the ball have more potential energy after it lands or at its highest point in the air? Explain.

___

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16. A rubberband is stretched as far as it can go. When it is stretched, what kind of energy is increased? When it is let go, what kind of energy increases? Explain.

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17. When you swing on a swing set, explain how energy changes from one form to another.

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18. Explain what kinetic energy is in your own words.

19. Give an example of kinetic energy.

20. What kind of energy does a plane have as it is waiting to take off?

Lesson Slides

The second type of energy is called thermal energy. Have you ever felt heat from a campfire? Have you seen chicken cook on a stove? People use thermal energy to cook food. Thermal energy changes the way food looks and tastes.

The third type of energy is sound energy. Sound energy happens when vibrations are carried by air or water. When you listen to the radio, you are listening to sound energy.

Kinetic energy is the energy of motion. Things that move have kinetic energy. This car is showing kinetic energy as it moves.

Light energy travels as waves. Light energy can come from the sun. Plants use light energy to help them make their food.

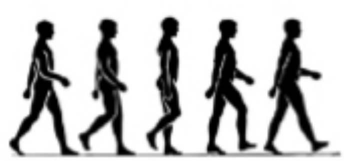
The last type of energy is potential energy. This type of energy is stored in objects. When the object moves, the energy comes out. It comes out as one of the five other types of energy. An airplane waiting to take off has potential energy.

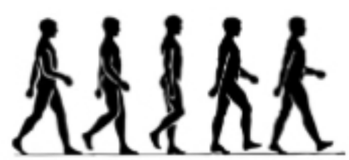
Let's review the six types of energy. Electrical energy is when electricity flows through a cord to power an object. Thermal energy is used when food is heated or cooked. Sound energy is when vibrations are carried by air or water.

Kinetic energy is the energy of motion. Things that move show kinetic energy. Light energy travels as waves. It helps plants make food. Potential energy is stored in an object. When it comes out, it turns into one of the other five types of energy.

Now we will look at potential energy and kinetic energy closely. Potential energy can turn into kinetic energy when it is released. This bike's potential energy is turned to kinetic energy when it starts moving.

Here is another example. You have potential energy when you are standing in one place. As you move, that potential energy has turned to kinetic energy. When you stop, potential energy is used again.

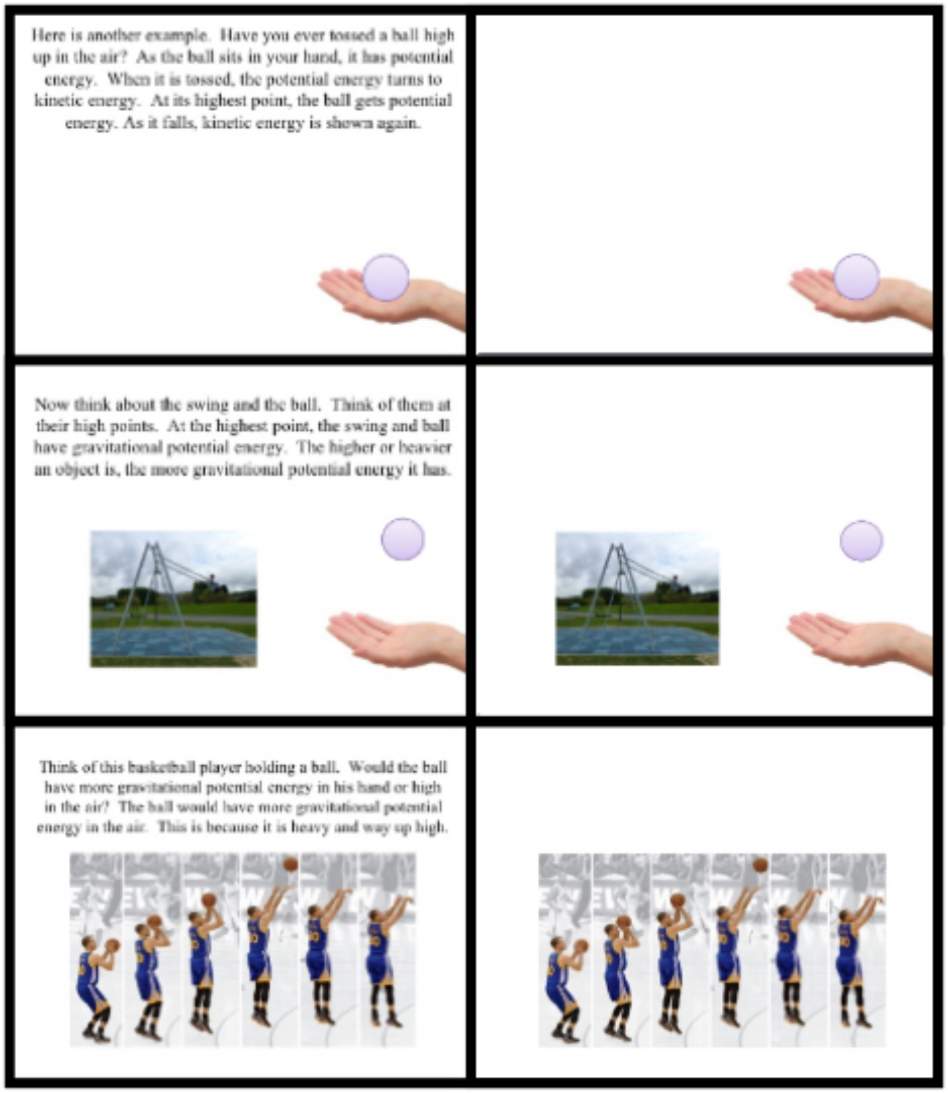




This bird also has potential energy. As it moves, its potential energy turns into kinetic energy. The first bird shows potential energy. Then it flaps its wings. This is kinetic energy. Remember, potential energy is stored energy. Kinetic energy is the energy of motion.

Objects that have potential and kinetic energy can show both kinds of energy. Look at this swing. It moves back and forth. As it moves, it shows kinetic energy. Can you see where it is has potential energy too?

Think about when you reach the highest point on a swing. You seem to stop for a moment. This is where kinetic energy changed to potential energy. This is when an object has the most potential energy.


Here is another example. Have you ever tossed a ball high up in the air? As the ball sits in your hand, it has potential energy. When it is tossed, the potential energy turns to kinetic energy. At its highest point, the ball gets potential energy. As it falls, kinetic energy is shown again.
Now think about the swing and the ball. Think of them at their high points. At the highest point, the swing and ball have gravitational potential energy. The higher or heavier an object is, the more gravitational potential energy it has.
Think of this basketball player holding a ball. Would the ball have more gravitational potential energy in his hand or high in the air? The ball would have more gravitational potential energy in the air. This is because it is heavy and way up high.

Remember the six types of energy? They are electrical, thermal, sound, light, kinetic, and potential. Try to remember one fact about each of these types now.

Now think about kinetic energy and potential energy. Objects can have potential energy that turns into kinetic energy. Then, kinetic energy can turn back into potential energy. This happens many times on fair rides. As an example, think about roller coasters.

What happens when an object is at its highest point in the air? It has the most gravitational potential energy. It will show kinetic energy when it falls.

I hope that you have learned a lot about the forms of energy today. As you use these different forms today, think about the types of energy you are using. Try to remember why energy is so important in your everyday life.

# Appendix C

## Reliability and Validity Materials

# Validity Rubric for Expert Panel – Instructional Materials

| Criteria | | Score | |
|---|---|---|---|
| | | YES | NO |
| Readability | Text and pictures are clear | 1 | 0 |
| | Word choice is appropriate for a 4th grade student | 1 | 0 |
| | Amount of time given to read slide is appropriate | 1 | 0 |
| Reflection between text and picture | Pictures are clear | 1 | 0 |
| | Pictures that accompany text reflect content | 1 | 0 |
| Additional Concerns/ Questions | | Total Score For Slide | |

Objectives:
1 – Students will recall that there are six types of energy
2 – Students will be able to identify a characteristic of each type of energy
3 – Students will be able to distinguish between different forms of energy when presented with real life examples
4 – Students will be able to explain differences between potential and kinetic energy

| Test Question | Objectives Addressed | | | | Comments |
|---|---|---|---|---|---|
| 1.Which of these is an example of energy? | 1 | 2 | 3 | 4 | |
| 2.Which one of these is an example of sound energy? | 1 | 2 | 3 | 4 | |
| 3. How many types of energy are there? | 1 | 2 | 3 | 4 | |
| 4. Which of these is a basic form of energy? | 1 | 2 | 3 | 4 | |
| 5. A car waiting at a red light has which of these types of energy? | 1 | 2 | 3 | 4 | |
| 6. What kind of energy is created by the sun? | 1 | 2 | 3 | 4 | |
| 7. What is the energy of motion called? | 1 | 2 | 3 | 4 | |
| 8. What kind of energy is stored in an object? | 1 | 2 | 3 | 4 | |
| 9. A car in motion is an example of what kind of energy? | 1 | 2 | 3 | 4 | |
| 10. What kind of energy do plants use to make their food? | 1 | 2 | 3 | 4 | |
| 11. Hamburgers cooking | 1 | 2 | 3 | 4 | |

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|---|---|---|---|---|---|
| on a stove is an example of what kind of energy? | | | | | |
| 12. A flag blowing in the wind is showing which kind of energy? | 1 | 2 | 3 | 4 | |
| 13. A boy is holding a baseball in his hand. He is ready to throw it. What kind of energy does the ball have as it is sitting in his hand? | 1 | 2 | 3 | 4 | |
| 14. Name two things in your school or house that use electrical energy. | 1 | 2 | 3 | 4 | |
| 15. During a kickball game, a ball is kicked high in the air. Does the ball have more potential energy after it lands or at its highest point in the air? | 1 | 2 | 3 | 4 | |
| 16. A rubberband is stretched as far as it can go. When it is stretched, what kind of energy is increased? When it is let go, what kind of energy increases? Explain. | 1 | 2 | 3 | 4 | |
| 17. When you swing on a swing set, explain how energy changes from one form to another. | 1 | 2 | 3 | 4 | |

| | | | | | |
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| 18. Explain what kinetic energy is in your own words.. | 1 | 2 | 3 | 4 | |
| 19. Give an example of kinetic energy. | 1 | 2 | 3 | 4 | |
| 20. What kind of energy does a plane have as it is waiting to take off? | 1 | 2 | 3 | 4 | |

# Scoring Rubric
## Assessment

| Question | Answer | Point Value | | Recall/Transfer |
|---|---|---|---|---|
| 1. Which of these is an example of energy? | a. a boy playing soccer | 0 | 1 | Transfer |
| 2. Which of these is an example of sound energy? | c. listening to your teacher read a story | 0 | 1 | Transfer |
| 3. How many types of energy are there? | a. 6 | 0 | 1 | Recall |
| 4. Which of these is a basic form of energy? | b. sound energy | 0 | 1 | Recall |
| 5. A car waiting at a red light has which of these types of energy? | b. potential energy | 0 | 1 | Transfer |
| 6. What kind of energy is created by the sun? | b. light energy | 0 | 1 | Recall |
| 7. What is the energy of motion called? | b. kinetic energy | 0 | 1 | Recall |
| 8. What kind of energy is stored in an object? | c. potential energy | 0 | 1 | Recall |
| 9. A car in motion is an example of what kind of energy? | c. kinetic energy | 0 | 1 | Recall |

| | | | | | |
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| 10. What kind of energy do plants use to make their food? | a. light energy | 0 | | 1 | Recall |
| 11. Hamburgers cooking on a stove is an example of which kind of energy? | a. thermal energy | 0 | | 1 | Transfer |
| 12. A flag blowing in the wind is showing which kind of energy? | b. kinetic energy | 0 | | 1 | Transfer |
| 13. A boy is holding a baseball in his hand. He is ready to throw it. What kind of energy does the ball have sitting in his hand? | d. potential energy | 0 | | 1 | Transfer |
| 14. Name two things in your house or school that use electrical energy. | *Students must name both for two points or one type for one point* | 0 | 1 | 2 | Transfer |
| 15. During a kickball game, a ball is kicked high in the air. Does the ball have more potential energy after it | *Students answer "at its highest point" for one point and give an explanation of potential energy for two points.* | 0 | 1 | 2 | Transfer |

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| lands or at its highest point in the air? Explain. | | | | | | |
| 16. A rubberband is stretched as far as it can go. When it is stretched, what kind of energy is increased? When it is let go, what kind of energy is increased? Explain. | *Students mention potential or kinetic energy for one point. They mention both potential and kinetic for two points. Three points for both and an explanation.* | 0 | 1 | 2 | 3 | Transfer |
| 17. When you swing on a swing set, explain how energy changes from one form to another. | *Students use kinetic and potential energy and explain at which point each is use.* | 0 | 1 | 2 | 3 | Recall |
| 18. Explain what kinetic energy is in your own words. | *Students give an acceptable explanation for the point.* | 0 | | 1 | | Recall |
| 19. Give an example of kinetic energy. | *Students give an acceptable example.* | 0 | | 1 | | Transfer |
| 20. What kind of energy does a plane have as it is waiting to | *Students answer potential energy.* | 0 | | 1 | | Recall |

| | | | | | |
|---|---|---|---|---|---|
| take off? | | | | | |