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The Comparative Effects of Visual-Only Instruction versus Modality Principle Instruction on Algebraic Problem Accuracy and Perceived Mental Effort at Varying Levels of Task Complexity for Undergraduate Nursing Students

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THE COMPARATIVE EFFECTS OF VISUAL-ONLY INSTRUCTION VERSUS MODALITY PRINCIPLE INSTRUCTION ON ALGEBRAIC PROBLEM ACCURACY AND PERCEIVED MENTAL EFFORT AT VARYING LEVELS OF TASK COMPLEXITY FOR UNDERGRADUATE NURSING STUDENTS

A Dissertation Presented to The Faculty of the School of Education Learning and Instruction Department In Partial Fulfillment Of the Requirements for the Degree Doctor of Education

by Kristina Viktorija Mattis San Francisco May 2012
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The Comparative Effects of Visual-Only Instruction versus Modality Principle Instruction on Algebraic Problem Accuracy and Perceived Mental Effort at Varying Levels of Task Complexity for Undergraduate Nursing Students

The purpose of this study was to compare the effects of two instructional formats on math accuracy and perceived mental effort during a series of math problems that varied in levels of complexity. The multimedia instruction results were compared against a traditional form of instruction using visual-only teaching materials.

Few studies examine the impact of instructional design on learning outcomes math instruction within nursing with a lack of research describing how math is taught to nursing students other than traditional lecture or textbook. Nursing students demonstrate low performance rates on math problems that involve mixed numbers that also tend to range in complexity levels.

One explanation is cognitive load. Research indicates that tasks of high complexity have negative effects on accuracy and perceived mental effort. Measuring perceived mental effort in addition to accuracy provides a stronger indicator of cognitive load because is performance assessed and the mechanics of the cognitive load processes. Understanding the cognitive load processes acts as a conduit to properly designing instruction specifically with the modality principle.

The modality principle shows positive effects on accuracy and perceived mental effort. The modality principle has a larger and more positive impact on learning outcomes when the learning material is complex because the instructional format reduces
cognitive load because of the visual and audio presentations.

Data were analyzed using independent t-tests between the two instructional groups based on three levels of complexity in addition to paired sample t-tests to examine the difference in scores from pre- to post-assessment.

Results indicated that while there was better accuracy with the instruction designed using the modality principle, perceived mental effort was rated higher than the control group that received visual-only instruction. Furthermore, ancillary analysis indicated that confidence was rated lower for the experimental group post instruction.
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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Acknowledgements

It feels like this journey began a long time ago, yet not so long ago, with endless days and nights of reading, conceptualizing, synthesizing, and analyzing. Ideas that led to nowhere, and others that developed from a microbial fragment into a wonderful new endeavor. This venture would not have come together if it were not for the following individuals. I would like to acknowledge my deepest appreciation and gratitude to…

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Dedication

This work that embarks on the journey to all future paths, is dedicated to those who strive for the pursuit of knowledge. May my children never fear to seek the unknown.

In the words of a fellow Illinoisan,

“If we value the pursuit of knowledge, we must be free to follow wherever that search may lead us.” – Adlai E. Stevenson, Jr.

In the words spoken by an educator who was fearless in exploring the unknown,

“Reach for it…Go push yourself as far as you can.” – S. Christa McAuliffe
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CHAPTER I

STATEMENT OF THE PROBLEM

Mathematics is assessed on certain exit exams in higher education, specifically in a concentration such as nursing where math is necessary within the field (Brown, 2006; Elliott & Joyce, 2004). The nursing population needs to be fluent in mathematical skills in order to accurately perform its responsibilities. For instance, nurses need to safely calculate medical dosages and correctly instruct patients on how to measure medications (Wright, 2009). Such procedures require the use of algebraic concepts that include mixed numbers (i.e. ratios, proportions, and percentages). In some cases, mathematics is not an explicit part of the instruction and at other times math is taught in an ineffective way that does not serve the goal of improving the mathematical skill set (Cosler, 1974; Costello, 2010; Harrell, 1987; Pappas & Allen, 1999).

According to Costello (2010), explicit mathematical instruction is deficient in nursing courses for at least two reasons. The first reason for the lack of explicit math instruction is due to the already time-sensitive and rigorous course material (Costello, 2010). Harrell (1987) explained that rather than instructors taking time out from class, nursing students are more often instructed to self-seek math textbooks designed specifically with medical mathematics. This type of passive instruction does not result in noticeable improvements (Harrell, 1987).

Second, the nursing course load is structured in a way that leaves little room for math instruction because the general assumption is that undergraduate students enter college with a sufficient knowledge and understanding of the content, specifically in algebra (Costello, 2010; Harrell, 1987). For example, calculation of intravenous drip
rates is based on the concentration of a specific drug and volume per unit of time or body weight per unit of time (Ogden & Fluharty, 2012). The formula is written as an algebraic equation. Despite the notion that more experienced, in essence older, students have a better understanding of algebraic problems than younger and less experienced students (Cooper & Sweller, 1985), research indicates that undergraduate nursing students experience noticeable deficits in mathematics achievement (Brown, 2006; Elliott & Joyce, 2004; Gillham & Chu, 1995). Specifically, Brown (2006) reported that nursing students demonstrate low performance on algebraic equations that directly require the use of fractions, decimals, and percentages that are readily seen in the medical field and typically vary in levels of complexity. To overcome such documented deficits, some form of explicit math instruction should occur as part of nursing education.

No research to date examines the impact of instructional design on learning outcomes in nursing education for these specific types of math problems. Cosler (1974) and Pappas and Allen (1999) suggested providing individualized instruction by designing instruction with computer or simulated settings in place of a traditional textbook or lecture-based instruction. Traditional learning environments refer to the presentation of learning material either through visual or verbal formats. For instance, textbooks convey information through visual text and images whereas lectures present information through verbal communication. Because there is typically only one mode of presentation, traditional instruction tends to create cognitive overload, an impairment to properly process and compute information with successful results (Costello, 2010). Even though lectures may combine verbal communication with visual images, the combination may not be designed appropriately to effectively relay information. Successfully designed
instruction provides a balance of information via verbal and visual contexts, thus effectively and efficiently utilizing both channels in what is referred to as the working memory.

Costello (2010) indicated that such instruction using technology could enhance undergraduate nursing student math skills. Educators have been expected to integrate technology into their instructional designs since its popularization in the classroom during the 1980s (Selwyn, 2007). A challenge for instructional designers, however, is to explore methods of raising learners' academic performance through appropriate uses of instructional technology (Center for Positive Practices, 2005). Unfortunately, very few research studies have compared the effects of traditional instruction and instruction designed with the use of technology, especially within the field of nursing. Furthermore, it seems as though it is no longer relevant to ask why an educator uses technology, but how to use the technology properly that benefits learning outcomes. Interestingly, though, with the appropriate integration of instructional technology, lies the need for more intricate understanding of the cognitive learning processes that also impact learning outcomes.

In addition to receiving little to no math instruction, task complexity and cognitive load processes such as prior knowledge and working memory could amplify poor math performance (Brünken, Plass, & Leutner, 2002; Mayer, 2009). Long-term memory primarily consists of prior knowledge as depicted in Figure 1. Prior knowledge is made up of several pieces of information that can either remain separated or be stored in schema. Schema is a structured knowledge framework that is typically organized
around relevant chunks of information increasing the efficiency of information storage, retrieval, and application.

Figure 1. Workings of long-term memory between prior knowledge and schema. The more prior knowledge that a learner possesses in a given subject increases the amount of schema that a learner can rely on. Additionally, the more schema a learner acquires decreases the potential for cognitive overload. Even though it is possible that some pieces of information within prior knowledge cannot be combined into chunks and thus not stored as efficiently as it would be within schema, a learner still retains that information. Regardless of where and how information is stored, the term prior knowledge is most frequently used to refer to the workings of long-term memory and schema.

Cognitive load is impacted not only by long-term memory, but also working memory. Figure 2 presents a schematic framework as to how working memory is connected to long-term memory. Working memory is considered to have two channels for processing information: visual and verbal (Baddeley & Hitch, 1974). For example, Miller (1956) argued that presenting instruction with only visual information overloads the processing efficiency of the visual channel; the same overload would occur if
instruction were to be presented with only verbal information. This type of overload occurs because the working memory has a limited capacity. Working memory capacity refers to the limited amount of information that can be processed at a given time (Miller, 1956). To decrease the potential of overload and to enhance the use of the limited working memory capacity, better learning outcomes are demonstrated when instructional design takes advantage of both the visual and verbal channels.

Figure 2. Schematic representation of working memory connected to long-term memory.

According to Paas, van Gog, and Sweller (2010), learners could be cognitively overwhelmed not just by the intrinsic impositions by long-term memory and working memory, but also by tasks that are considered to be highly complex. Task complexity refers to the number of components that are needed to be simultaneously cognitively processed in order to solve a given task. As task complexity increases, a greater strain is placed on the already limited working memory capacity, especially if a learner’s long-term memory does not contain enough prior knowledge or schema for a given task. For instance, nursing students tend to show sufficient prior knowledge by successfully completing math problems using whole numbers; however, there is performance failure
on problems including mixed numbers such as decimals, fractions, and percentages that naturally involve higher levels of complexity (Brown, 2006; Mayer, 2009; Sweller, 1988). Without proficient levels of prior knowledge on more complex tasks, working memory can be overloaded, thus hindering positive outcomes on performance.

Chandler and Sweller (1991) revealed connections between instructional technology and cognitive learning processes in addition to learning outcomes through the cognitive load theory developed by Sweller (1988). Sweller’s theory postulates that there are three cognitive loads that learners endure: intrinsic, extraneous, and germane. Intrinsic load is personal because it depends on the amount of long-term memory that a learner has and is further imposed upon by the complexity of the content to be learned. Extraneous load pertains to the design of the instruction; specifically, instruction that is designed using irrelevant or unnecessary information. Germane load is impacted by effectively designed instruction that engages long-term memory through schema acquisition. When considering cognitive load during the instructional design process, intrinsic and extraneous loads should be minimized whereas germane load should be maximized.

Figure 3. Sweller’s (1988) schematic representation of cognitive load theory.
Despite critical commentary by Goldman (1991) and Dixon (1991) toward the Chandler and Sweller study, Resnick (1991) stresses that the line of studies were not meant to further test the cognitive load theory, but to use the theory as a conduit in designing instruction using technology. Thus, previous research emphasizes that instructional technology must be properly designed, be meaningfully beneficial for learners and learning outcomes, and consider the learning processes such as long-term memory, working memory, and task complexity (Azevedo, 2002; Brünken, Plass, & Leutner, 2002; Clancey & Soloway, 1990). Using instructional technology designed with the cognitive learning processes in mind to provide explicit math instruction could be adapted into time-constricted programs such as nursing while improving performance and alleviating cognitive load such as mental effort (Paas, Tuovinen, Tabbers, & van Gerven, 2003). The notion is that mental effort decreases as accuracy increases in part because cognitive load is alleviated through effectively designed instruction.

Designing instruction through multimedia is one such solution to the poor math performance of nursing students, because not only does it take into account the intricacies of instructional technology and the cognitive learning processes while positively impacting learning outcomes (Brünken, Plass, & Leutner, 2002), but it also can be distributed via video format that students could watch on their own time, and thus, be adapted into the curriculum without taking away from direct class time while providing explicit instruction on tasks that range in complexity levels.

The modality principle is one multimedia learning design that takes into account such cognitive learning processes which also positively affects learning outcomes (Mayer, 2009). The modality principle is a multimedia instructional design method using
technology through which learning material is presented with a simultaneous combination of visuals and audio (Mayer, 2009). In his early studies, Mayer (2001) concluded that converting text to audio while simultaneously presenting images enhances opportunities for meaningful learning to occur such that learners indicate good retention and good transfer performance. The outcomes of meaningful learning, according to Mayer (2009), depended on the “cognitive activity of the learner during learning rather than on the learner’s behavioral activity during learning” (p. 3). In essence, Mayer studied what the learner does cognitively rather than behaviorally. In later studies, Mayer (2009) emphasized that specifically using audio adjacent to dynamic images that involve movement such as animations, slide shows, or video recordings of handwriting facilitated even greater opportunities for meaningful learning.

Mayer’s (2009) modality principle postulates designing instruction with this format because learning material is presented simultaneously through visual and audio components with the consideration of working memory. As a result, designing instruction using the modality principle enhances the limited uses of working memory capacity. Presenting complex learning material through instruction designed with the modality principle has been known to alleviate the learner’s cognitive load by balancing information between the two visual and verbal working memory channels (Kalyuga, Chandler, & Sweller, 1999; Tindall-Ford, Chandler, & Sweller, 1997). Sweller’s (1988) cognitive load theory argues that the amount of pressure or stress placed upon a learner’s mental activity during the learning process often hinders the learning outcomes. For instance, the specific design of instruction and personal learner characteristics such as long-term memory and working memory impact cognitive load. When the limited
working memory capacity is made more efficient, there is a possibility that cognitive load decreases, specifically on tasks of higher complexity. Mayer’s (2009) studies suggest that when tasks are highly complex, designing instruction using the modality principle produces positive learning outcomes by increasing accuracy while decreasing perceived mental effort when long-term memory is low on a given task (Tindall-Ford, et al., 1997).

With regard to nursing students who may not have sufficient prior knowledge when solving mixed-number equations involving different levels of complexity, conveniently integrating explicit instruction using the modality principle could provide the necessary information to enhance performance without taking additional class time. Even though Ginns (2005) and Mayer (2009) reported positive outcomes when using the modality principle in the fields of mathematics and science, and Costello (2010) looked at computer-based instruction within the field of nursing, there is no research specifically examining the impact of the modality principle on mathematical performance at various different levels of complexity and cognitive learning processes within the field of nursing.

**Educational Significance**

There are three reasons why this study was educationally significant. First, designing instruction using the modality principle allowed a way to overcome the time constraints in nursing courses because instruction can be provided outside of class via video format. Second, instruction using the modality principle alleviated cognitive load and in turn enhanced learning outcomes. Third, the results from this study extended Mayer’s previous studies using the modality principle by exploring its effects at different levels of complexity.
Understanding the impact of cognitive load on learning processes and outcomes acted as a conduit to instructional design using the modality principle. This current study provided further evidence on the impact of multimedia instruction using the modality principle. Even though applying the modality principle is possible within a variety of content areas, conducting this study with a focused sample of nursing students was ideal because this population has documented performance deficits when solving certain types of mathematical problems despite math being an integral aspect to the profession.

**Theoretical Rationale**

With the consideration of needing effective instruction and the cognitive learning processes, Mayer developed a cognitive theory of multimedia learning (CTML; 2001), which served as the conceptual foundation for this current study. CTML integrates cognitive load theory (Sweller, 1988) and dual-coding theory (Paivio, 1986), with underlying references to working memory (Baddeley, 1986; Baddeley & Hitch, 1974; Miller, 1956) into a comprehensive understanding of how people learn from multimedia instruction. Multimedia is a form of instruction that simultaneously uses more than one format to present learning material. Learning through multimedia instruction is grounded in Mayer’s (2009) findings that people learn better from words and pictures than from words alone.

Based on Mayer’s model of CTML, as depicted in Figure 4, learning material is presented through words and pictures, which are then processed through the ears and eyes into sensory memory. Words, if spoken, enter the sensory memory through the ears; however, if words are presented as text, they enter sensory memory through the eyes. Pictures are always visual, thus entering the sensory memory through the eyes. Notice
that in Mayer’s model (Figure 4), a learner must first select relevant information, then organize that information by making connections among the selected information, and finally integrate that selected and organized information into existing knowledge (Mayer, 2001; 2009; Moreno & Mayer, 2002). A learner can then store the new information into long-term memory for future retrieval.

![Mayer's Multimedia Model](image)

*Figure 4. Mayer’s (2009) model of cognitive theory of multimedia learning.*

Reed (2006) considers Mayer’s CTML an instructional theory because it allows educators to consider the cognitive learning processes when designing instruction using multimedia. CTML is based on three assumptions. First, there are two channels that process information in working memory: visual and verbal, (Baddeley, 1992; Paivio, 1986). Second, both channels are limited in capacity to process new information at any one given time (Baddeley, 1992; Baddeley & Hitch, 1974; Chandler & Sweller, 1991; Miller, 1956). The third assumption is based on active processing, which means that learners actively work to develop an understanding from the information processed in each channel by selecting relevant information, organizing that information in a coherent way, and then integrating that information with prior knowledge (Mayer, 2008).

Mayer (2009) refers to three sources of processing in his model of cognitive theory of multimedia learning: essential, extraneous, and generative. Even though the definitions of essential, extraneous, and generative processing are similar to that of
Sweller’s intrinsic, extraneous, and germane loads as depicted in Figure 3, Mayer’s
theory serves as the theoretical foundation for this current study, thus his terms will be
referenced throughout.

Essential processing is the amount of cognitive load placed on working memory
by the level of task complexity. Essential processing overload occurs when the amount
of prior knowledge and the level of task complexity exceed a learner’s working memory
capacity. When then learner’s working memory capacity is exceeded, there is a negative
learning effect. Mayer also suggests that poorly designed instruction can also negatively
impact essential processing (Mayer, 2005a).

Extraneous processing is the cognitive load placed on working memory produced
by the instructional conditions and learning environment. Typically, extraneous
processing is a negative situation because the instructional conditions and the learning
environment tend to confuse a learner. Extraneous processing refers to irrelevant
instructional material not necessary to complete the task and does not serve the
instructional goal. It should be noted, though, that it may be possible for learners to
perform well during poor instruction if the learning material is considered low in
complexity. As cognitive load increases, however, the learning outcomes decrease if
learners receive poorly designed instruction when task complexity is high.

Generative processing requires a deeper level of understanding and is most likely
brought on by the intrinsic motivation of the learner. According to DeLeeuw and Mayer
(2008), generative processing refers to learners engaging in a mental organization of
learning material and relating that material to prior knowledge. If extraneous and
essential processing demands are too high, then it becomes difficult for students to experience generative processing.

CTML combines the use of technology and the cognitive learning processes through the use of multimedia instruction and may help instructional designers overcome their challenge in appropriately integrating technology into a learning environment. Additionally, instructional designers are able to consider the cognitive learning processes while developing instruction by following the CTML.

**Background and Need**

The background and need section provides an overview of research that has explored mathematical problem solving within nursing education and the uses of multimedia in mathematical learning environments. Using multimedia instruction is considered effective because it combines instructional technology and the cognitive learning processes. A specific design of multimedia instruction is the modality principle. An explanation of modality principle instruction and its positive results will be reviewed. Lastly, a section related to the direction for current research concludes this section that lends support for the basis of this current study.

**Mathematical Problem Solving**

Mathematical problem solving is a vast area of research. Only a few areas of this field are referenced in this section because of the explicit relevance for the purposes of this current study. For larger reviews regarding mathematical problem solving, refer to Polya (1957), Mayer (2002), and Schoenfeld (1985; 1994) in addition to Silver’s (1985) edited book and reviews written by Mayer and Schoenfeld (Alexander & Winne, 2006).

The National Council of Teachers of Mathematics considers superior problem-
solving skills as a way to succeed in mathematics, especially because problem-solving ability is assessed in the classroom and on mandated standardized tests (NAEP, 2009; NCTM). Chi and Glaser (1985) defined a problem as a situation that covers a large range of difficulty and complexity, requires an end goal, and necessitates finding a way to reach that goal. An example of such a situation is solving an algebraic equation. Algebraic equations can range in complexity based on the number of elements, or steps, required to successfully solve the problem. Complex algebraic equations are often seen in nursing and require an accurate solution in order to correctly administer medications to patients.

Mayer (1985) addressed problem solving as a multi-step process that required the problem solver to establish relationships between prior knowledge and the problem at hand with an end goal of successfully implementing a plausible solution. Sweller and Cooper (1985) further supported the notion that learners should be able to demonstrate an ability to solve problems with various strategies while drawing upon prior knowledge.

Palumbo (1990) made the connection that the more learners are able to solve problems in realistic and essential situations, the more experience and knowledge they gain. Palumbo’s distinction furthers the claim that schema is critical during mathematical problem solving. Funkhouser and Dennis (1992) regarded problem solving as a process that involves manipulating or operating on previous knowledge in order to find a solution to a problem. This is important because nurses would rely on their knowledge and understanding when calculating proper drug administrations for patients.

There has been debate whether to use numerical equations or word problems when assessing algebraic equation problem-solving ability. Research provides evidence that one of the main concerns when it comes to low problem-solving performance on
word problems is the lack of understanding of what the problem is asking (Lim, 2000; Mahmud, 2003), or the type of language used (Keller, 1939; Zakaria & Yusoff, 2009; Zakaria, 2002). Daniel and Embretson (2010) distinguished that even though equations that are presented in words require more processing steps than numerical-only problems, item difficulty did not increase. Such problems, however, could be associated with increased errors. Alternatively, verbal language from doctors’ orders and textual language written in a patient’s chart require nurses to understand the specific language that is used. In this study, the word problems were structured in an authentic way that nursing students would see in their work environments.

**Nursing Math Education**

The sample of participants in this study consisted of undergraduate nursing majors early in their nursing program. A key feature for nursing majors is that mathematics is a professional necessity as compared to other chosen non-mathematical majors. Even though an understanding of algebra is needed in the nursing profession, studies indicate that nurses lack certain mathematic skills. (Brown, 2006; Elliott & Joyce, 2004; Gillham & Chu, 1995).

Gillham and Chu (1995) assessed the drug calculation abilities of 158 undergraduate second-year nursing students by administering a 10-item test of common clinical calculations. Their results indicated that only 88 students (55%) answered all questions correctly. Gillham and Chu noted that students had a limited understanding of basic arithmetic. According to Gillham and Chu, 22 students made calculation errors that could be deemed clinically dangerous.
Elliot and Joyce (2004) administered a 20-question exam to 130 first-year nursing students who were allowed to use calculators. Students were given three attempts to pass the exam, receiving feedback and remedial work to help improve their knowledge and scores between each attempt. By the third attempt, 25 students still scored at a failing percentage (75% or below). Elliot and Joyce explained that most errors were considered simple miscalculations and that upon receiving feedback, it was discovered that students did not understand the intent of the items.

Most interestingly was a study conducted by Brown (2006). Brown reported that while cumulative scores indicated that nursing students were mathematically prepared overall, stratified scores of individual test items presented evidence that nursing students scored below the passing mark on items that involved algebraic concepts specifically needed in the nursing profession. Results indicated poor performance on algebraic problems involving decimals, percentages, and fractions.

Brown reached his findings by administering an adapted version of the Computational Placement Test of the College Board to a sample of first-semester nursing students in 1988 and 2003. The Computational Placement Test was designed for individuals who completed less than one year of algebra in high school. In both the 1988 and 2003 sample groups, over 90% of the students had finished at least one year of algebra, with more than 56% having completed more than two years of algebra.

Brown’s results showed a mean test score of 76% for the 1988 sample and 77% for the 2003 sample. Brown reported that students in both sample groups were considered mathematically prepared because a score of 75% is considered passing in most colleges similar to that of Elliot and Joyce (2004); however, many institutions
consider above 70% as passing.

According to Brown’s discussion, most students correctly solved items that involved simple addition, subtraction, multiplication, and division of whole numbers. When analyzing the results by individual test items, Brown indicated that students from both sample groups actually demonstrated difficulty with addition, subtraction, multiplication, and division when fractions, decimals, and percentages were involved. Table 1 replicates Brown’s findings. Correct answers ranged from 38% to 92% in 1988 and 42% to 97% for the 2003 sample. Students’ responses from the 1988 sample scored 70% or less on 10 items; the 2003 sample scored 70% or less on 11 items. Eight of the items were common between sample groups that included subtracting, multiplying, dividing mixed fractions, and a combination of multiplying and dividing decimals or a conversion between decimals and fractions. Brown stressed that such skills on such problems are needed for medication administration.
Table 1

Illustrative Items with less than a 70% Average Correct Response Rate for Years 1988/2003 (Brown, 2006)

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Item</th>
<th>Student Response (1988) in %</th>
<th>Student Response (2003) in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3 ½ - 1 2/3</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>2</td>
<td>1 5/7 * 2 * 2</td>
<td>63</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>1/3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10/1/05</td>
<td>58</td>
<td>67</td>
</tr>
<tr>
<td>4</td>
<td>6 yd 1 ft 9 in – 2 yd 2 ft 10 in</td>
<td>56</td>
<td>58</td>
</tr>
<tr>
<td>5</td>
<td>880 / 0.8</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>6</td>
<td>1/200 change to decimal</td>
<td>43</td>
<td>42</td>
</tr>
<tr>
<td>7</td>
<td>1.6 change to fraction</td>
<td>40</td>
<td>65</td>
</tr>
<tr>
<td>8</td>
<td>2 1/3 / 1 ½</td>
<td>38</td>
<td>52</td>
</tr>
</tbody>
</table>

The math problems in this current study included decimals, percentages, and fractions using equations from the 10 low performing items in the Brown (2006) study written in a way that are seen in the nursing profession requiring participants to calculate conversions. An example item would read as follows: “A patient’s chart reads that you are to administer 6.95 mls for the 1st hour and 7.61 mls each hour after. By what percent to you increase the dosage?” This problem involves decimals and percentages in addition to multiplying and dividing. The complexity level of this problem was considered high. Calculating conversions may add additional levels of complexity to the solution process causing a negative affect on perceived mental effort and, in turn, accuracy. Examining the effects of instruction using the modality principle on perceived mental effort and
accuracy lent further insight into learning environments that involve varying levels of
task complexity.

There are debates on the use of calculators when assessing students on math
problems. Unlike the Elliot and Joyce (2004) study, Brown did not allow calculators to be
used in completing math problems. To pacify such disagreements, Shockley (1989)
explained that though the use of calculators decreases the amount of arithmetic errors,
there tends to be an increase in conceptual errors. This means that regardless of having
access to a calculator, a student will not calculate a correct answer if the conceptual
knowledge lacks. Another flaw in the Halford et al. (2005) study is that it is unclear if
the researchers allowed the use of calculators. For the purpose of this current study,
participants were able to use calculators to solve the math problems because it would
alter the ability to demonstrate accuracy if the conceptual set up was incorrect.

Modality Principle Instruction

Mayer (2009) defined the modality principle as a multimedia instructional design
format through which “people learn more deeply from pictures and spoken words than
from pictures and printed words” (p. 200). Pictures can be either static or dynamic.
Static pictures do not have motion whereas dynamic pictures can range from animated
videos, slideshows, or a real-time recording of handwriting. For instance, a real-time
recording using a document camera could be handwriting the solution to a math problem.
Spoken words are typically operationalized narrations or recorded audio.

Mayer (2001) claimed that presenting material through words and pictures
fostered meaningful learning such that learners indicate good retention and good transfer
performance. In later studies, Mayer (2009) emphasized that specifically using audio
adjacent to dynamic images that involve movement such as animations, slide shows, or video recordings of handwriting facilitated even greater opportunities for meaningful learning. The outcomes of meaningful learning, according to Mayer (2009), depended on the “cognitive activity of the learner during learning rather than on the learner’s behavioral activity during learning” (p. 3).

With the use of modality principle, Mayer tested Paivio’s (1986) dual-coding theory in that both visual and verbal information are processed differently and Baddeley and Hitch’s (1974) working memory model. Mayer repeatedly found that students’ learning was consistently better when learning materials were presented with narration and an image, regardless of either static or dynamic images (Mayer, Hegarty, Mayer, & Campbell, 2005). Mousavi, Low, and Sweller (1995) referred to the balance of narration and visual images within working memory as modality off-loading. Modality off-loading is meant to alleviate the potential for cognitive overload, allowing for more efficient use of the limited working memory capacity.

Mayer (2009) demonstrated in each of his 17 tests that participants performed better on problem-solving tasks when dynamic or static pictures were simultaneously presented with narration resulting in a median effect size of $d = 1.02$. Theoretically, these results were in line with Mayer’s notion that participants were not expected to split their attention on either the visual or verbal channels in working memory with the use of the modality principle. Mayer (2005a) further proposed that the modality principle could be more effective when the learning material is unfamiliar. When cognitive load is reduced, the learning experience is enhanced (Mayer & Moreno, 1998).
Research from a variety of sources indicates that providing learners with narrated dynamic images about a given topic enhances academic learning outcome performance (Brünken, Plass, & Leutner, 2003, 2004; Ginns, 2005; Harskamp, Mayer, & Suhre, 2007; Low & Sweller, 2005; Mayer, 2005a; Moreno, 2006; Moreno & Mayer, 1999a, 1999b, 2002; Moreno, Mayer, Spires, & Lester, 2001; Mousavi, et al., 1995; Seufert & Brünken, 2006; Seufert, Schutze, & Brünken, 2009). The studies that specifically incorporated the modality principle in mathematical problem-solving learning environments presented results with strong effect sizes (Atkinson, 2005; Ginns, 2005; Jeung, Chandler, & Sweller, 1997; Mayer, 2009).

In theory, we know that visual-only instruction has negative impacts on learning outcomes based on Mayer’s (2001) cognitive theory of multimedia learning, Paivio’s (1986) dual-coding theory, and Baddeley and Hitch’s (1974) working memory model. General research provides further evidence of the negative impacts caused by visual-only instruction (Mayer, 2001; 2009; Mayer & Moreno, 2002; Scheiter, Gerjets, & Schuh, 2010). This could leave one to wonder as to why include visual-only instruction as part of a study. One main reason is that educational settings continue to use visual-only instruction typically as seen in textbooks (Costello, 2010). Thus, a visual-only learning environment lended support as a traditional instructional method and a control group for this current study.

Considering the theoretical outcomes for this study, accuracy was hypothesized to decrease in both groups as complexity increases; however, the experimental group receiving instruction using the guidelines of the modality principle was theorized to not
decrease in accuracy as much as the control group receiving visual-only instruction as depicted in Figure 6.

![Hypothesized Results](image)

**Figure 6.** Hypothesized results for accuracy between treatment groups at different levels of complexity.

Even though research on the uses of the modality principle provides evidence of positive learning outcomes, Mayer (2009) suggested that the research conducted on the use of the modality principle has limitations. One such limitation has been the lack of research on the modality effect at different levels of complexity. In line with Mayer’s suggestion, this study examined that limitation, specifically in the field of mathematics instruction. It was anticipated that the experimental group receiving instruction with the modality principle would outperform the control group, but the exact impact of the modality principle at other levels of complexity was unknown.

**Task Complexity**

Task complexity is in part dependent on the number of pieces of information, known as elements, that have some kind of interacting relationship among each other and
must be processed at any one given time (Ellen & Clark, 2006; Sweller, 1999). Ellen and Clark further pointed out that the characteristics of the task in addition to the characteristics of a learner influence complexity. In conjunction with Ellen and Clark, Mayer (2009) proposed that complexity is based not only on the learning material but also on the amount of a learner’s prior knowledge. The amount of prior knowledge may indicate the level of chunked information a learner has within schema as illustrated in Figure 1.

![Figure 1. Workings of long-term memory from prior knowledge and schema.](image)

To reiterate, the more prior knowledge a learner has, specifically prior knowledge that has been stored in schema, the greater the opportunity for learners to absorb new information without adding additional pressure on cognitive load.

When task complexity is low, each element can be understood without needing to reference or learn relevant connections. For example, low task complexity could be learning a series of new vocabulary words because the words are unrelated to each other. In this case, there is little imposition on working memory load. High task complexity, on the other hand, means that the individual elements cannot be understood as a whole until
all elements and interactions are processed simultaneously (Paas, Renkl, & Sweller, 2003). For instance, when learning the proper grammatical syntax for the words, understanding not only the meaning of the words but also the order in which the words are placed could be considered high element interactivity. In this example, there is a heavier imposition on working memory. The added amount of load based on level of task complexity will differ depending on the schema levels of the learner.

Paas and van Merrienboër (1994) developed a schematic representation including causal factors related to cognitive overload depicted in Figure 7. One causal factor that could lead to cognitive overload is the task at hand. The specific task impacts the type of assessment factors that influence cognitive processes such as mental load, and simultaneously the amount of mental effort that learners expend. Performance, as a result, could be either positively or negatively affected.

Figure 7. Schematic representation of the causal and assessment factors that contribute to cognitive load (Paas and van Merrienboër, 1994).

Kirschner (2002) specified that a task of high complexity impacts cognitive load more so
than just any given task, especially one that may be considered simple. For example, mathematical problem solving tasks range from low to high task complexity and directly impact essential processing (Mayer, 2009; Tabbers, 2001). Sweller and Chandler (1994) noted that much of mathematics involves high complexity because many elements interact and cannot be processed individually. The more sophisticated the task, the more complex the elements become, creating higher levels of complexity. Sriraman (2003) claimed that presenting well-constructed learning materials with highly complex math tasks is crucial if learners are meant to develop higher order and sophisticated math skills.

One study that examined varying levels of task complexity was conducted by Halford, Baker, McCredden, and Bain (2005). Tasks included visual-only instruction involving visual bar graphs and textual prompts that related to each other. Halford et al. (2005) explored the effects on working memory capacity by measuring accuracy as task complexity increased for a group of 30 participants. Based on the participants’ areas of expertise, the researchers presumed that there would be a sufficient level of prior knowledge to perform the math tasks at hand. Results suggested, however, that accuracy decreased as task complexity increased regardless of the participants’ implied level of prior knowledge. The researchers assumed that working memory capacity was not as efficient on tasks of high complexity than on tasks that were considered low in complexity because participant’s cognitive processes were overloaded. One limitation in that study was that the researchers did not explicitly measure perceived mental effort and prior knowledge.
Purpose of the Study

If there is any form or amount of math instruction within nursing, very few studies, and much less current research, examine the impact of instructional design on learning outcomes. Moreover, there is a lack of research describing how math is taught to nursing students other than what is considered to be traditional by way of lecture or textbook (Costello, 2010).

As reported by Brown (2006), nursing students demonstrate low performance rates on math problems that involve fractions, decimals, and percentages. Such math problems also tend to range in complexity levels. One explanation for low performance on those specific math problems is cognitive load. Measuring perceived mental effort in addition to accuracy can provide a stronger indicator of cognitive load because not only is performance assessed but also the mechanics of the cognitive load processes can be studied (Moreno, 2005; Paas & van Merrienboër, 1994). Understanding the cognitive load processes acts as a conduit to properly designing instruction specifically with the modality principle.

Thus far, research on the modality principle has reported positive effects on accuracy (Mayer, 2009) and perceived mental effort (Sweller, van Merrienboër, & Paas, 1998; Tabbers, Martens, & van Merrienboër, 2001; Tindall-Ford, et al., 1997). Research also indicates that tasks of high complexity have negative effects on accuracy and perceived mental effort (Halford, et al., 2005). Kalyuga, Chandler, and Sweller (1999) and Tindall-Ford, Chandler, and Sweller (1997) noted that the modality principle has a larger and more positive impact on learning outcomes when the learning material is complex because the instructional format reduces cognitive load because of the visual
and audio presentations. A balanced presentation of visual and audio information utilizes the working memory visual and verbal channels more effectively and efficiently (Baddeley & Hitch, 1974).

Mayer’s (2009) suggestion indicates the need for an the investigation of the limitations of the modality principle at varying levels of task complexity. Similar to Halford et al.’s study, the intent for this study was to provide subjects with problems that vary in complexity. The extension beyond Halford et al.’s study was to compare the effects of two instructional formats and to explicitly assess accuracy and perceived mental effort as task complexity increases.

The purpose of this study was to compare the effects of two instructional formats on math accuracy and perceived mental effort during a series of math problems that varied in levels of complexity through a quasi-experimental research design. The multimedia instruction results were compared against a traditional form of instruction using visual-only teaching materials (Costello, 2010). Measuring perceived mental effort in addition to accuracy provided a stronger indicator of cognitive load because not only is performance assessed but also the mechanics of the cognitive load processes can be studied (Moreno, 2005; Paas & van Merrienboer, 1994). Results on accuracy and perceived mental effort were analyzed using independent t-tests between the two instructional groups based on three levels of complexity in addition to paired sample t-tests to examine the difference in scores from pre- to post-assessment.

**Research Questions**

Because of the small sample size, a pre-assessment was conducted; however, given that the primary interest of this study was to analyze the results of the post-
assessment after participants received one of the two forms of instruction, there were two research questions that guided this study. The first research question focused on the dependent variable of accuracy whereas the second research question focused on the dependent variable of perceived mental effort. The two research questions that guided this study were:

1. Does instruction using the modality principle result in better accuracy as compared to visual-only instruction at each level of complexity as indicated by post-assessments?

2. Does instruction using the modality principle result in lower perceived mental effort when compared to visual-only instruction at each level of complexity as indicated by post-assessments?

Summary

Thus far, we know that the field of nursing relies on math knowledge, but that undergraduate nursing students have demonstrated deficits on math problems that include fractions, decimals, and percentages (Brown, 2006). Furthermore, nursing students either do not receive explicit math instruction or the instruction is so minimal that there are no actual improvements. Two primary reasons for the lack of explicit math instruction are one, that nursing students are thought to have sufficient math knowledge and two, that nursing courses are designed to emphasize actual medical training. In general, in order to perform well on mathematical tasks, certain cognitive issues arise such as prior knowledge, working memory, and task complexity, in addition to the cognitive aspects of instructional presentation. If nursing students do not have sufficient prior knowledge or effective instruction to rely on, the math problems may be too complex and thus overload
the limited workings of working memory creating a cognitive overload. Unfortunately, such issues may negatively impact learning outcomes such as accuracy and the cognitive learning processes such as cognitive load by way of perceived mental effort (Paas, Tuovinen, Tabbers, & Van Gerven, 2003).

Even though the modality principle can be applied to instructional design for a variety of content areas, one particular content area that could significantly benefit from this form of instruction is mathematics because there are various levels of complexity. Mayer proposed that mathematical problem solving is a multi-step process that requires the problem solver to establish relationships between prior knowledge and the problem at hand with the end goal of successfully implementing a plausible solution. Cognitive learning processes are relevant concerns in mathematics; therefore, Mayer views mathematical problem solving from a cognitive load perspective. Mayer’s (2001) research has shown that the modality principle has a positive effect on accuracy for learners with low amounts of prior knowledge in a given field such as mathematics because cognitive overload is reduced.

Despite the connection between the modality principle and positive outcomes on tasks of high complexity, Mayer (2009) suggested future research should explore the principle’s limitations. One such limitation is that no studies have explicitly tested the modality principle and its effects on accuracy and perceived mental effort at other levels of task complexity other than high. There are connections between the modality principle and variables such as prior knowledge, working memory capacity, task complexity, accuracy, and perceived mental effort for tasks of high complexity. For instance, we know that the modality principle is beneficial when highly complex learning material is
presented, but we do not know if the modality principle is equally effective at all levels of complexity or if its effect changes as complexity increases (Ginns, 2005; Mayer, 2009). We also do not have a clear understanding at which point the modality principle no longer holds a positive impact or perhaps even has a negative effect. Based on Mayer’s suggested limitation, this current study provided further insight on accuracy and perceived mental effort when using the modality principle at varying levels of task complexity specifically for nursing students when solving algebra equations involving mixed numbers.

**Definitions of Terms**

**Cognitive Load Theory**: A learning theory that is based on the assumption that a human’s working memory has only a limited capacity to store information. Cognitive load theory describes the distribution of working memory resources during the learning process (Sweller, 1988).

**Cognitive Theory of Multimedia Learning**: A learning theory based on the assumption that people possess dual channels for processing verbal and visual information, that each channel is limited in how much information it can process, and that meaningful learning involves engaging and actively processing information appropriately (Mayer, 2001).

**Dual Coding Theory**: A learning theory that is based on the assumption that both visual and verbal information is processed along different channels in the brain (Paivio, 1986).

**Essential Processing**: is the amount of cognitive load placed on working memory by the task complexity of the learning material (Mayer, 2009).

**Extraneous Processing**: is the cognitive load placed on working memory created by the instructional conditions and learning environment (Mayer, 2009). Typically, extraneous
processing is a negative situation because instructional conditions and the learning environment are confusing for a learner.

**Generative Processing:** requires a deeper level of understanding and most likely brought on by the intrinsic motivation of the learner (Mayer, 2009).

**Perceived mental effort:** A measure of the perceived level of cognitive energy that must be spent when performing an instructional task (Paas & van Merrienboër, 1993).

**Modality Principle:** The modality principle presents learning material with simultaneous visual and audio presentations, allowing for the human cognitive architecture to be more balanced. The balance allows for better dual-channel processing that alleviates cognitive overload and more efficient use of the limit capacity of working memory (2005b).

**Multimedia:** A form of communication that uses words and pictures to foster meaningful learning (Mayer, 2001).

**Schema:** A long-term memory structure that is the basis for content expertise and meaningful learning (Sweller, et al., 1998). Used to select relevant information, include new information to existing knowledge, and then develop a mental model of their understanding (Braune & Foshay, 1983). Similar to Mayer’s (1985) schema formation.

**Task Complexity:** Task complexity refers to the difficulty level of a task. Refers to the way individual elements of a task interact with one another.

**Working Memory:** A limited and multifaceted cognitive information storage and processing system (Baddeley, 1986).
CHAPTER II
REVIEW OF LITERATURE

With the intent of designing instruction using the modality principle having a more positive effect on learning outcomes when tasks are considered highly complex, there have been known limitations of the modality principle with material of different complexity levels (Mayer, 2009). The purpose of this current study was to compare the effects of the modality principle instruction versus visual-only instruction at varying levels of complexity on perceived mental effort and accuracy. Specifically, this study examined the cognitive learning processes and outcomes for undergraduate nursing students and mathematics.

Sweller’s (1994) cognitive load theory, Paivio’s (1986) dual-coding theory, and Baddeley and Hitch’s (1974) working memory model was reviewed to better understand the foundation of Mayer’s cognitive theory of multimedia learning (CTML). Each of these theories affects learning and instructional design for better learning outcomes. Descriptions of cognitive learning processes such as long-term memory and impact of task complexity will follow. A section acknowledging more in-depth research on the two dependent variables, accuracy and perceived mental effort, is presented in addition to a sub-section of research explaining how to measure those variables under the cognitive load premise. The modality principle section will present previous research on its application in mathematics and connections between cognitive learning processes and learning outcomes. Grounding the variables in a prior study, an overview of a study conducted by Halford, Baker, McCredden, and Bain (2005) is described. Finally, the gaps in the literature will shed light onto the research questions for this current study.
Cognitive Load Theory

Mayer grounds part of his cognitive theory of multimedia learning in Sweller’s (1994) cognitive load theory. Similar to Mayer’s theory, Reed also considers cognitive load theory as an instructional theory because it directly takes into account the cognitive and learning processes (Reed, 2006). Cognitive load theory is based on a cognitive architecture consisting of a limited working memory that interacts with an unlimited long-term memory (Chandler & Sweller, 1992; Sweller, et al., 1998). Cognitive load theory aligns the limitations of working memory capacity with instructional design to reduce cognitive load in order to facilitate the components of long-term memory: prior knowledge and schema (Sweller, 1988). Since its inception, cognitive load theory has influenced educational psychology and instructional design (Paas, Renkl, et al., 2003; Paas, Renkl, & Sweller, 2004; Paas, et al., 2010; Sweller, 1988; Sweller, et al.; van Merrienboër & Sweller, 2005). The theory provides a theoretical foundation for designing instructional materials to best enhance learning and to avoid overwhelming a learner’s cognitive resources.

Cognitive load refers to the amount of load placed on working memory during instruction, and the theory provides a way to assess cognitive limitations in terms of learning and instruction (Sweller, 1988). Cognitive load theory assumes that knowledge acquisition depends on the efficiency of the use of available, yet limited, cognitive resources within working memory (Paas, Renkl, et al., 2003). Because working memory capacity is limited, the theory proposes that learners can be cognitively overwhelmed by high levels of task complexity, and from improperly designed instruction (Paas, et al., 2010). Unless considering the cognitive system of a learner, instructional design could
lead to cognitive overload (Clark, Nguyen, & Sweller, 2006).

Types of cognitive load. As previously depicted in Figure 3 of the first chapter, there are three types of cognitive load that make up the resources used in learning: intrinsic, extraneous, and germane. Sweller’s (1993) primary focus was on intrinsic load because of its direct relation between the learning content and the learner. After additional research along side other cognitive load researchers, Sweller included extraneous and germane cognitive loads. Extraneous and germane cognitive loads are thought to be influenced by instructional design (Sweller, et al., 1998).

**Figure 3.** Sweller’s (1988) schematic representation of cognitive load theory.

Intrinsic load. Intrinsic load tends to receive more attention than the other two types of load because “Intrinsic load is the mental work imposed by the complexity of the content” (Clark, et al., 2006, p. 9). In fact, when Sweller (1993) initially described intrinsic load, he claimed that the presented information was more influential than instructional design. The level of complexity of learning materials depends on the number of elements that must be simultaneously processed on a given task. The higher the task complexity, the higher the intrinsic load (Gyselinck, Jamet, & Dubois, 2008;
Mayer, 2008). Intrinsic load also varies depending on schema. The more expertise a learner has in a given field, the more schema that learner has to rely upon to complete a task. Intrinsic load can be reduced on a task if instruction provides a learner with additional schema, thus freeing working memory capacity to process more and perhaps different information. Any available working memory resources remaining after dealing with intrinsic cognitive load can be allocated to deal with extraneous and germane cognitive load.

**Extraneous load.** Extraneous cognitive load occurs when irrelevant and unnecessary information hinders learning the task at hand and depends entirely on instructional design. For example, if there is an advertisement with information that takes away from the actual point of the product, that extra information is extraneous. Another example of extraneous load is when a learner does not have the adequate schema and is not provided with the necessary information to complete a task. For instance, when someone is asked to reference a dictionary to find a word without ever having used a dictionary before, the pure task of using a dictionary much less trying to find a word within the dictionary would be considered extraneous. It should be noted, though, that if intrinsic load is low, then chances are that the extraneous load is not of great importance because the total cognitive load may not exceed the limited working memory capacity. Paas, van Gog, and Sweller (2010) argued that to best manage the limited working memory capacity and to foster schema acquisition, simply eliminate all possible extraneous load.

**Germane load.** Like extraneous load, instructional design also influences germane load but in a way that is meant to enhance learning rather than impede it (Sweller, 1988).
Germane load corresponds to learning process effort (Gyselinck, et al., 2008). Germane sources promote learning by helping students engage in the process of schema acquisition. Schema acquisition occurs as elements of information are organized in an order with which they was dealt (Sweller, 1988). As a learner’s schema develops for future retrieval of information from long-term memory, that learner gains expertise in a given domain. Such expertise alleviates the potential for cognitive overload. Moreover, as schema develops from increasing expertise, learners are able to treat what once were multiple elements as single chunks, or units. This, in turn, also decreases intrinsic cognitive overload leaving room for more germane load to accrue in working memory (van Merrienboër & Sweller, 2005).

**Cognitive overload.** For instruction to be effective, the combination of intrinsic and extraneous loads should not exceed a learner’s limited working memory capacity because otherwise there is not enough room for germane load to take place (Kalyuga, Renkl, & Paas, 2010). Intrinsic load is thought to be implicit based on a learner’s level of schema and the complexity level of a task. Both extraneous and germane cognitive load can be altered by instructional design.

**Dual-coding Theory**

Dual-coding theory (Paivio, 1986) is a foundation for Mayer’s cognitive theory of multimedia learning because many of Mayer’s principles take advantage of combining visual and verbal information in multimedia instructional design. Reed (2006) considers Paivio’s theory as a dual-coding theory because it makes a distinction between two modes of learning material when designing instruction: visual and verbal. There are two cognitive processing channels - verbal and visual. Dual-coding theory assumes that
presenting visual and verbal information simultaneously provides a better opportunity for processing information (Paivio, 1986). By utilizing both channels simultaneously, information is more readily retrievable from working memory (Brunye, Taylor, Rapp, & Spiro, 2006). Paivio’s theory is supported by Baddeley’s working memory model wherein he proposed that there are separate channels for the phonological loop relating to verbal information and visual-spatial sketchpad relating to visual information.

Processing verbal and visual information compared to text alone is thought to result in a dual coding of information, which in turn is easily accessible in long-term memory.

Although one might expect these competing sources of information to cognitively overload a learner, the simultaneous presentation of corresponding and simultaneous verbal and visual information offsets the overloading of information on one channel by balancing the dual-channel processing experience (Mayer, 1997). In turn, cognitive load is alleviated.

**Working Memory**

Working memory is a limited cognitive information storage and processing system (Baddeley, 1986). Working memory supports the ability to retain and utilize information needed to complete tasks that are considered complex such as reasoning and comprehension. Cognitive load researchers have considered working memory as a system that can only be managed by manipulating instructional formats (Paas, et al., 2010). Instructional format manipulation can increase the efficiency of the limited working memory capacity and can reduce the amount of cognitive load (Mayer, 2001; Tabbers, Martens, & van Merrienboër, 2004). Figure 2 of the first chapter represents a schematic representation of the pathway form working memory to long-term memory.
Figure 2. Schematic representation of working memory connected to long-term memory.

There are two key issues that come out of working memory: limited capacity and there are two channels, verbal and visual. Similar to Paivio’s dual-coding theory, Reed (2006) views Baddeley’s working memory model as a multimodal theory because it too distinguishes the importance between verbal and visual components when learning and when designing instruction. Each of these issues should influence the design of instruction. Instructional design should also take into account the workings of long-term memory, which primarily consists of prior knowledge. Prior knowledge refers to pieces of information that can either remain separated or be chunked together based on relevancy. If information is chunked, it is then stored in schema. As a result, a learner’s long-term memory is connected to the efficient use of working memory.

Miller (1956) claimed that there is a limited capacity of information that working memory can take in and still effectively function. According to Miller, that limited capacity is comprised of seven pieces of information, with a leeway of plus or minus two. These single pieces of information are called elements. Elements could remain as single pieces, but when the elements have common interactions, they can be combined into
single units called chunks. One element could be something like one word, one number, or one name. A chunk, for instance, could be a combination of three numbers. For example, three single numbers such as 4-1-5 could be remembered as one chunk such as an area code, 415. The more chunks a person can create, the more free space there is in the limited working memory for additional information.

Working memory capacity and its efficiency can negatively or positively impact cognitive load, perceived mental effort, and accuracy. Successful learning and performance depends on the efficient use of available working memory cognitive resources (Paas, Renkl, et al., 2003). When the limited working memory capacity is split because information is presented on only one channel, a high cognitive learning load and a learning detriment occur (Mayer & Moreno, 1998; Paas, Renkl, et al., 2003; Sweller & Chandler, 1994). Therefore, if learning material is balanced with visual and audio information, the use of the limited working memory capacity becomes more efficient (Baddeley, 1992). Furthermore, there is a decrease in cognitive load. Accuracy also improves for learners who measure at lower levels of working memory capacity with instruction designed using the modality principle (Atkinson, 2005; Ginns, 2005; Mayer, 2009; Moreno, et al., 2001).

Since Miller’s claim of limited working memory capacity, studies have investigated its accuracy. Research stipulates that Miller’s limitations of seven plus or minus two elements should be adjusted to four elements, plus or minus two (Conway, Kane, & Engle, 2003; Cowan, 2000, 2005; Halford, Bain, Maybery, & Andrews, 1998 & Andrews, 1998; Halford, et al., 2005 & Bain, 2005; Luck & Vogel, 1997). These studies have indicated that as problem-solving tasks increase in complexity, performance
decreases. Previous studies have reviewed task complexity and differences in working memory arguing that when elements interact, working memory capacity is lowered to about four elements (Beckmann, 2010; Halford, et al., 2005; Halford & Busby, 2007; Halford, Cowan, & Andrews, 2007; Hoffman, McCrudden, Schraw, & Hartley, 2008; McConnell & Quinn, 2004). Sweller, van Merriënboer, and Paas (1998) explained that when information is meant to be processed rather than retained for memory, learners can manage only two to three elements simultaneously.

Cowan (2000) went as far as to explain that performance on tasks can decrease with even less than four elements not only because individuals demonstrate different limitations of working memory capacity but also because of the level of task complexity. Task complexity refers to the level of information a learner is required to process simultaneously. This means that high levels of task complexity such as algebraic linear equations requiring multiple steps to solve may affect the limited working memory capacity. Instruction using the modality principle could positively support learning environments where learners are expected to process different levels of complexity.

Baddeley and Hitch (1974) built upon Miller’s work and suggested that working memory has two very distinct, yet highly connected, components that initially process visual and verbal information independently - the phonological loop is responsible for the processing of verbal information, and the visual-spatial sketchpad that enables the processing of visual and spatial information as shown in Figure 8. Both the phonological loop and visual-spatial sketchpad systems interchange information between the central executive system.
These processes facilitate better recall of information when learning material is presented on both the visual and verbal channels rather than one (Baddeley, 1992). When learning material is presented through only the visual-spatial sketchpad or the phonological loop, learners split their available, yet limited, working memory capacity (Baddeley, 1992, 2000). Studies have shown the influence of these limitations on information processing especially on performance in cognitive tasks (Anderson, Reder, & Lebiere, 1996; Just & Carpenter, 1992), such as mathematics.

Baddeley revisited the model of working memory by adding a third distinct component called the episodic buffer, which is thought to have a connection to either long-term memory or semantic meaning because it allows for interrelating details from visual, spatial, and verbal information (2000). Visual information refers to what the learner sees, spatial refers to the spacing and placement of the visual information, and verbal information refers to what the learners hears. Little research, though, has been conducted with the episodic buffer.

**Central executive.** Once information is understood, stored, and retrieved from prior knowledge, the central executive selects necessary information to store in long-term memory for future retrieval. Long-term memory is vast because it retrieves information
that has already been absorbed in the central executive (Baddeley, 1996), similar to that of schema. The central executive monitors and coordinates the operation of the systems. It also selects the necessary information on which to focus, stores information in long-term memory, and then retrieves information within working memory when that information is necessary for use. Each aspect of working memory is assumed to have its own limited cognitive resources that act relatively independent from each other; however, the resources are associated with each other during many tasks. For instance, if two concurrent tasks make use of the same working memory component there was an interference between the resources (Klauer & Zhao, 2004).

**Phonological loop.** According to Baddeley’s (1992) updated reference of phonological loop, this system processes and stores acoustic and speech-based information. The auditory information is transferred into the central executive for long-term memory storage. Baddeley noted four effects within the phonological loop. First, the acoustic similarity effect explains that item recall is worse when sounds are similar rather than dissimilar. Second, irrelevant speech effect occurs when there is poor recall of visually presented lists of words combined with irrelevant spoken words. Third, word-length effect refers to the ability to recall as many words as can be said in two seconds. The fourth and final effect is articulatory suppression that disrupts learning if someone is required to repeat an irrelevant sound such as the word *the*. For example, when learning a new word such as *eucalyptus*, saying *the eucalyptus leaf* could be more detrimental than saying *eucalyptus leaf*. The word *leaf* would not be detrimental because it is relevant in creating a context for the word *eucalyptus*.

When using audio, instructional designers should take these effects into account.
Additionally, Leahy and Sweller (in press) caution that audio length could affect learners’ performance. For example, reducing statement length could reduce working memory load. In the second experiment of their study, Leahy and Sweller found better performance from participants when instruction using the modality principle was presented in less than 15 minutes. The 15-minute time frame was determined by calculating the total sum of the length of time for each slide and audio presented to the participants. With regard to designing the instruction using the modality principle in this current study, Baddeley’s four effects and Leahy and Sweller’s length suggestion was taken into account.

**Visual-spatial sketchpad.** Logie presented a more in-depth view of the visual-spatial sketchpad by suggesting two subcomponents: visual cache, which stores visual information regarding form and color, and inner scribe that relates to spatial and movement information (Logie, 1995). Smith and Jonides (1997) based their study on Logie’s proposal and reported that working memory tasks that included visual objects activated the left-brain hemisphere whereas working memory tasks that included spatial information activated the right-brain hemisphere. This means that in order to utilize the whole brain during visual-spatial-only presentations, a critical balance of form, color, spatial and movement information should be considered in the instructional design process (Smith & Jonides, 1997).

**Episodic buffer.** In more recent versions of the working memory model, the episodic buffer was added as a system that allows for binding information from visual, spatial, and verbal information (Baddeley, 2000). The episodic buffer is thought to have a connection to either long-term memory or semantic meaning. Unfortunately, because
there is a lack of research regarding the episodic buffer, little can be empirically supported.

Ignoring the framework of working memory and its limitations is a deficit in instructional design (Sweller, et al., 1998). Because of the independence of the working memory processing systems, the amount of information presented at a given time might overwhelm one of those systems. This can be better managed by balancing information across both the visual and verbal channels. The modality principle provides instruction by simultaneously combining visual information with verbal information, thus offsetting the load from one channel and making the use of the limited working memory more efficient by balancing the instruction visually and verbally (Kirschner, 2002). Mayer and his colleagues have found this to be true in numerous studies (Mayer, 2001). Because the modality principle provides instruction by simultaneously combining visual information with verbal information, understanding the workings of working memory for this current study provides necessary information sensitive to the design of instructional presentations using the modality principle. With regard to this study, the modality principle can increase the efficiency of limited working memory capacity, thus improving accuracy and perceived mental effort.

**Long-term Memory**

Instructional design can positively or negative impact long-term memory. Likewise, the limitations of working memory capacity could be positively or negatively affected by long-term memory. Long-term memory is also impacted by prior knowledge and schema as demonstrated in Figure 1 of the first chapter.
Figure 1. Workings of long-term memory from prior knowledge and schema.

Moreno (2010) pointed out that processing information specifically relates to prior knowledge and Sweller (1994) referred to the process in which information is organized as schema. The information processed in prior knowledge, however, may not transfer into schema. Instances in which this happens may be due to stand-alone information that does not relate to anything else or that the learner does not sufficiently understand the information to successfully integrate into schema.

Schema determines how to rearrange and then unite newly presented information, or elements, with existing knowledge. The more schema a person acquires, known as schema acquisition, the more readily available knowledge there is to process information into chunks. By combining several single pieces of information into one chunk through schema acquisition, the amount of information that can be held in working memory is increased. Schema acquisition also alleviates the pressures placed on the limited capacity of working memory.

The more information that is processed and stored in schema, the more cognitive resources are available for other activities (Sweller & Chandler, 1994). Although schema can hold a large amount of information, it is processed as a single chunk in working
memory. Mayer (1992) proposed that meaningful learning occurs when a learner selects relevant information, organizes that information in a logical whole, and integrates that information with appropriate schema.

Schema formation is acquired from long-term memory and is essentially an individual’s knowledge base. Schema formation refers to the categorization of information in the manner that they were used. Even though the number of separate pieces of information to simultaneously process is limited in working memory, the complexity of that information is not. Skilled performance on a task requires increasing the amount of more complex schema by combining information from low schema levels to higher levels of schema. By doing so, it is thought that schema may reduce working memory load despite the already-established limitations (Sweller, et al., 1998). Therefore, schema has two functions: to store and organize information in long-term memory and to reduce working memory load. Sweller, van Merrienboër and Paas (1998) argued that this should be a key role in education.

With the cognitive benefits of schema regarding schema formation, the reduction of working memory load, and the increased used of cognitive resources, the information processed in schema is more advanced as compared to prior knowledge. Therefore, schema was referred to in this current study, though this study will not independently control for learners’ schema processing.

**Long-term Memory and Expertise**

Novak (1990) asserted that learners construct concepts from prior knowledge. Johnson and Lawson (1998) argued that prior knowledge is a critical factor when determining learning. According to Mayer (1992), learners build upon prior knowledge
by using working memory to select relevant information, add new information to existing knowledge, and then develop a mental model of their understanding. Determining prior knowledge for this current study is necessary to gauge complexity levels of math problems and to adequately design the instructional treatment.

Prior knowledge is the knowledge retained in long-term memory for future use. When actively processing information to make mental constructs, Mayer (2001) refers to this as schema. Mayer explained that learning is an active process requiring learners to filter, select, organize, and integrate information based upon their given prior knowledge. The more schema a learner has, the more knowledge there is retained in long-term memory. Thus, learners have more of an opportunity to cognitively access information from prior knowledge. Novak (1990) claimed that learners construct concepts from prior knowledge and thus, Johnson and Lawson (1998) argued that prior knowledge is a critical factor when determining learning.

According to Braune and Foshay (1983), learners tend to use prior knowledge to select relevant information, include new information to existing knowledge, and then develop a mental model of their understanding. When processing information, such individual differences specifically relate to prior knowledge (Moreno & Park, 2010). Although schema can hold a large amount of information, it is processed as a single unit in working memory. In this manner, cognitive schemas reduce the load on a working memory system limited to only a few elements of information at one time (Kalyuga, et al., 1999; Kirschner, 2002).

Kujawa & Huske (1995) explained that prior knowledge is a combination of a learner’s pre-existing attitudes, experiences, and knowledge. Even though Kujawa and
Huske related their definition of prior knowledge to literacy, it seems applicable to a variety of content areas. Attitudes pertain to beliefs about the learner as self, awareness of personal interests and strengths, and the motivation and desire to perform a task. Experiences include everyday activities, events that provide background understanding, and family and community experiences that are brought to any given learning experience. Knowledge includes a myriad of possibilities, but most relevant are knowledge of content, topics, and concepts.

Clark, Ngyuen, and Sweller (2006) alluded to individual differences such as prior knowledge as an important issue when studying cognitive load. Prior knowledge is a direct connection to cognitive load (Brünken, Seufert, & Paas, 2010) because it influences the amount of mental load that is placed on a learner. Inadvertently but equally as important, the amount of cognitive load placed on a learner may impact the amount of perceived mental effort a learner dedicates toward a task. Thus, prior knowledge influences a learner’s perceived mental effort and accuracy (Paas, Tuovinen, et al., 2003; Paas & van Merrienboër, 1993).

Another causal factor of cognitive load can be a learner’s characteristics through cognitive abilities such as expertise (Kirschner, 2002). When it comes to prior knowledge, learners can be considered as either expert or novice. Typically, research has compared differences in cognitive structures and processes of experts and novices (Chi, Feitovich, & Glaser, 1981; Chi & Glaser, 1985). In order to problem solve successfully, a certain level of expertise is needed (Chi, et al., 1981; Chi & Glaser, 1985; Chi, Glaser, & Rees, 1982; Kalyuga, et al., 2010). Expertise depends on prior knowledge and prior experience, and Palumbo (1990) expressed that problem solving depends on both.
Palumbo also argued that the more learners are able to solve problems in realistic and essential situations, the more experience and knowledge they gain. Cautiously, though, just because a learner has prior knowledge and prior experience does not necessarily create an expert. More so, a learner could have a great deal of prior knowledge regardless the type of experience had.

Expertise develops from schema and automated knowledge. Once information is formulated into long-term memory, that knowledge becomes automated for future use. Such automated knowledge does not require much use of limited cognitive resources, specifically working memory thus allowing for the freed space in working memory to be used to acquire additional knowledge or to be applied to higher levels of cognition (Cooper & Sweller, 1987; Kalyuga, 2010). A major function of expertise is the ability to recognize higher-order elements that are then related to lower-order elements. Having the level of expertise to interpret higher-order elements lends to the ability to apply that knowledge to the interpretation of element interactions. Additionally, Kalyuga noted that expertise could lend to more efficient and effective use of the limitations of processing capacity in working memory, thus lessening the amount of perceived mental effort needed to perform a task. Research into expertise has not shown a difference in the amount of working memory capacity of an expert when compared to the working memory capacity of a novice, but studies do show a difference in the efficiency of working memory capacity between experts and novices (Kalyuga, 2010).

A difference between a novice and an expert in a certain domain is in the quantity and organizational quality of available knowledge (Chi, et al., 1982). Experts are able to treat many elements as one single, higher-order element, thus reducing the information-
processing demands on working memory and alleviating the amount of perceived mental effort placed on completing a task. For example, what could be one chunk for an expert could be 10 chunks for a novice. Even though working memory capacity does not change as a learner gains expertise (Sohn & Doane, 2003), an expert will activate a schema that categorizes a problem on its structural properties as a single chunk in working memory and follow an appropriate path to a solution when presented with a new task. Novices, on the other hand, do not possess these schemata leading to a high cognitive overload (Sweller, 1988).

Research into expertise has not shown a difference in the amount of working memory capacity of an expert when compared to the working memory capacity of a novice, but studies show a difference in the efficiency of working memory capacity between experts and novices (Kalyuga, 2010). Even though working memory capacity does not change as a learner gains expertise (Sohn & Doane, 2003), an expert will activate a schema that categorizes a problem on its structural properties as a single chunk in working memory and follow an appropriate path to a solution when presented with a new task. Novices, on the other hand, do not possess these schemata and, as a result, resort to using weak problem-solving strategies such as means-end analysis, which leads to a high cognitive overload (Sweller, 1988).

Even though expert problem solvers may be able to use their working memory resources more effectively regardless of single- or dual-channel representations (Shah, Freedman, & Vekiri, 2005), the limits of working memory capacity cannot be exceeded (Halford, et al., 2005). In some regard, it does not matter whether an individual is an expert or novice because of the irreversible limitation of working memory capacity. It
does matter, however, how an individual utilizes and processes the given information within the limits of working memory capacity. In the case of experts compared to novices, experts have an advantage because they can utilize schema and organize information in fewer chunks. There are two variations to working memory capacity: the capacity of working memory ranges within its limits meaning that people can have a working memory capacity ranging from two to six elements, and working memory has the potential to be used more effectively and efficiently based on instructional design. It should not be a goal to increase the limits of working memory capacity, but to enhance its efficiency.

Specifically related to algebraic problems, Lewis (1981) examined the differences in solutions of experts and novices. Lewis noted that experts tend to restructure the terms of the original problem into more of an abstraction of the elements of the problem whereas novices do not. By doing so, experts have the ability to reformulate complex expressions into simpler ones that allow for more appropriate manipulations. By doing so, experts can readjust their mental load and balance differently the effort needed for solving the problem.

Less experienced and novice learners do not have the ability to monitor as well and make necessary changes to problem solve successfully. Adelson (1984) found that when presented with problems, novices are less abstract in thinking when compared to experts and tend to focus more on surface features. Schoenfeld (1994) cautioned that novices might continue using unsuccessful strategies throughout the process. Essentially, novices have a dependence on limited previous knowledge of strategies and approaches regardless of the chance of success. Such control decisions, whether expert or novice,
tend to be based on the personal belief system, which is developed from personal experience.

Task Complexity

Determining complexity. Determining varying levels of task complexity was first approached by Sweller (1994) from a cognitive load perspective. Sweller suggested that complexity could be measured by the amount of steps taken to solve a problem or how many elements interact with one another. Elements are considered single pieces of information. According to Sweller, task is low in complexity when elements can be learned in isolation and that a problem can be solved with such isolated elements. Alternatively, if understanding a concept can be done only when simultaneously combining and making connections among several elements, then a task is considered high in complexity. Essentially, complexity levels depend on the number of steps it takes a learner to solve a problem and the conceptual demand of setting up a problem. In line with this study, designing math problem-solving items at different complexity levels is important because it is a way to measure ability and achievement (Daniel & Embretson, 2010).

There is little research on how to ascertain task complexity levels and how to accurately conclude what is considered more or less complex outside of the cognitive viewpoint (Daniel & Embretson, 2010). Moreover, the lack of empirical research for determining item difficulty within a task prior to the development of such items or before the task is administered leaves many researchers to revert to anticipatory levels of item complexity. Even though some studies have attempted to design models or indexes to rate task complexity prior to item development, Daniel and Embretson noted that
determining specific item complexity levels within a task typically involves defining the difficulty levels after the items have been developed, such as is the case in this current study.

Like Sweller, Beckmann (2010) also viewed complexity through a cognitive load lens proposing that altering the tasks at hand is a way to change the level of task complexity. For example, if changing the task at hand changes what needs to be learned, then learning is reflective of essential processing. However, if changing the task at hand does not change what needs to be learned, then learning is reflective of extraneous processing. Beckmann’s contemplation directly relates to instructional design regardless of the content domain.

Because this current study used math as the content for comparing different instructional designs, referring to prior research for determining different complexity levels in mathematics was most logical. For instance, Johar and Ariffin (2001) developed a difficulty index for math problems. Problems ranging between 0.20 and 0.80 could be used as a baseline to quantify the difficulty level of a test item. Any item over 0.30 is considered a good item and items closer to 0.80 are considered high in difficulty. The index, however, has rarely been applied to latter studies and thus has little empirical or practical support for its use. Alternatively, the linear logistic test model provides some form of predictability of item difficulty. Similar to that of the Johar and Ariffin index, however, such models are not routinely applied and thus do not provide sufficient empirical evidence for usability.

Without empirical support, the 2005 National Center for Education Statistics proposes and defines three levels of mathematical complexity: low, moderate, and high.
Low complexity relies on recall and recognition of previously learned concepts. Learners could mechanically carry out procedures without an original method or solution. Moderate complexity allows for more flexibility in developing a solution and problems typically have two or more steps. Learners are expected to synthesize skill and knowledge from various domains and apply them to the solving process. High complexity places the most demand on learners. Learners must engage in sophisticated abstract reasoning, planning, analysis, judgment, and creative thought.

Reverting to Sweller’s view of complexity provides a more defined view of determining low, moderate, or high levels of complexity. Because Sweller’s (1994) and Beckman’s (2010) cognitive load perspectives seem to be the most-used ways of determining task complexity, this study anticipated that items would range in complexity based on the number of steps taken to solve a problem and that the design of the instruction will reflect essential processing rather than extraneous processing. Even though each succeeding category would increase in complexity, there would be a range of complexity levels within one category as well. A potential limitation in assessing complexity, though, is that there is more than one way to solve a mathematical problem. Some learners may solve math problems more efficiently than others depending on a learner’s level of prior knowledge, thus impacting the number of steps and conceptual demand to solving problems.

Complexity levels could also be determined simply by calculating the amount of correct and incorrect answers per problem (Brown, 2006). For instance, 0-33% correct indicates a difficult problem, 34-67% correct indicates a moderately complex problem, and 68-100% correct indicates an easy problem. For this current study, complexity was
established by percent of accuracy. The fewer amount of correctly answered problems were considered more difficult in complexity because there were too many elements for participants to comprehend to successfully solve.

**Research with task complexity.** Other than measuring the amount of steps taken to solve a problem or how many elements interact with one another, there is little research on how to design mathematical items that vary in cognitive complexity level (Daniel & Embretson, 2010). For instance, even though Johar and Ariffin (2001) developed a difficulty index for math problems, the index has rarely been applied to later studies. There have been studies, though, that look at the effects of task complexity on working memory, accuracy, and overall problem-solving ability.

Kemps (2001) investigated the effect of complexity on the visual-spatial channel in working memory, specifically short-term memory. Results indicated that the involvement of long-term memory processes plays a role in the ability to retain and recall information through short-term memory at various complexity levels. As part of the conclusions, Kemps suggested that the effect of complexity might act as an underlying negative consequence to the limitations of the visual-spatial short-term memory. Kemps’ findings are of interest in this current study because long-term memory is part of prior knowledge and this study will focus on varying task complexity levels on working memory.

McConnell and Quinn (2004) reviewed task complexity and its affect on visual-spatial sketchpad working memory. Their study concluded that when the complexity was increased at various intervals, an increased disruption on the visual-spatial sketchpad portion of working memory occurred. The complexity that was used in their study was a
manipulation of the phonological loop. In future studies, it would be beneficial to examine the effects of complexity on the phonological loop after manipulating the visual-spatial sketchpad, especially in mathematics. For this current study, though, there was a comparison between instruction using the modality principle and visual-only instruction. The form of instruction that participants receive will manipulate working memory.

Hoffman, McCrudden, Schraw, and Hartley (2008) investigated the influences of task complexity between concrete and abstract syllogisms on working memory and problem solving. Results indicated that participants were able to better perform on concrete syllogism than abstract ones. This is of interest to this current study because algebraic equations are considered to trigger abstract thinking. Hoffman et al. (2008) noticed an efficiency paradox. The efficiency paradox is a trade off between task complexity and performance as measured by accuracy and time spent on task. For instance, participants were more efficient in solving problems at lower levels of task complexity. As a possible result, Hoffman and colleagues suggested that accuracy might have decreased because less time was spent on such problems. Alternatively, the efficiency of problem solving decreased as task complexity rose. Accuracy on higher levels of task complexity may have increased because participants spent more time on those tasks. Even though efficiency will not be measured in this current study, a participant’s level of prior knowledge may influence the amount of perceived mental effort placed on a given problem and the ability to perform accurately.

Beckmann (2010) looked at cognitive load by using complexity-based approximations to predict performance by conducting a study that measured the effects of working memory capacity based on increased levels of task complexity. Beckmann used
a broad participant range to obtain a wide sample of cognitive abilities and ages in order to better generalize his findings. There were three sample groups: 74 university students ranging from 19 to 32 years, 73 young adults with non-traditional schooling ranging from 16 to 23 years, and 84 pensioners with tertiary schooling ranging from 60 to 84 years. Beckmann verified that with an increase in age, cognitive abilities and performance on reasoning tasks have been shown to decrease and processing speed has been shown to increase.

Beckmann (2010) hypothesized that performance would decrease as task complexity increased because of the constraints placed on cognitive load. As such, the results indeed showed a significant effect that performance decreased as complexity increased. Beckmann further investigated his findings and explained that even though overall performance decreased, the performances among varying cognitive ability groups differed. The different cognitive ability groups demonstrated individual mean differences in processing and storage capacity, and cognitive abilities such as reasoning.

Results in Beckman’s study indicated that higher task complexity levels decreased accuracy. In the same study, accuracy either increased or decreased depending on the learner’s level of prior knowledge. For each of Beckmann’s results, the young adult sample performed the lowest among the three sample groups. This was not a finding that Beckman anticipated because Beckmann made explicit notation that with age, performance should decrease. In this case, however, the older adults performed similarly to the university students. A possible implication of the younger group not performing is the inability to reason as well as the university or older group. Another possibly could be a difference between traditional and non-traditional education. Reasoning could be a
cognitive ability that improves with age and education. In a future study, it would be beneficial to explore reasoning by measuring the effects of the modality principle on perceived mental effort and accuracy at varying levels of complexity for sample groups similar to those in Beckman’s study.

Beckmann’s study further supported Sweller’s (1988) cognitive load theory because the presentation format reduced cognitive load regardless of cognitive ability. Hoffman et al.’s (2008) efficiency paradox is similar to Beckmann’s (2010) claim of altering the tasks at hand as a way to change the level of task complexity. For example, if changing the task at hand changes what needs to be learned is reflective of essential processing. However, if changing the task at hand does not change what needs to be learned is reflective of extraneous processing. The modality principle is meant to decrease both intrinsic and extraneous processing loads.

Beckmann, however, did not measure working memory capacity during or after the study to gain insight as to how working memory capacity was affected by increased task complexity. The level of complexity is a characteristic of a given task (Paas & van Merrienboër, 1994a), and the limitations of working memory capacity are reflections of the level of task complexity (Beckmann, 2010; Sweller & Chandler, 1994). Unfortunately, Beckmann’s study lacks exploration on how to combat limitations of working memory capacity. It would be of interest in a future study to explicitly measure working memory capacity during a pre-assessment and examine its effects on performance after receiving instruction with the modality principle.

Accuracy

Paas (1992) defined performance as “the effectiveness in accomplishing a
particular task,” and that it is often times measured by speed, accuracy, or test scores. Shortly thereafter, Paas and van Merrienboër (1993) stressed that accuracy was an objective form of assessment, which DeLeeuw and Mayer (2008) reported is associated with generative processing. Task complexity and prior knowledge either positively or negative impact a learner’s ability to perform accurately. Bandura (1986) explained that prior experiences affect performance ability in terms of accuracy on future tasks that are similar in nature. Consistent with previous findings, Pajares (1996) also hypothesized and demonstrated that prior achievement in mathematics, specifically algebra, affects performance accuracy.

Perceived Mental Effort

Perceived mental effort refers to the cognitive capacity actually allocated to the task and is based on students’ ability to compensate the increase in cognitive load with the amount of effort placed on a task (Paas & van Merrienboër, 1994b). Cognitively, there is a direct connection between perceived mental effort and essential processing (DeLeeuw & Mayer, 2008). The level of a learner’s schema affects that individual’s essential processing load. Paas and van Merrienboër (1994a) cautioned that only measuring perceived mental effort as a way to assess essential processing is not effective and may not be accurate. For instance, essential processing load could be deemed high if a learner measures low perceived mental effort because that learner cannot cognitively manage to allocate more attention to the given task. Alternatively, essential processing load could be viewed as low when perceived mental effort is measured high. Similarly, essential processing could be low if perceived mental effort is rated low because of a learner’s high level of prior knowledge. Thus, measuring only perceived mental effort as a way to
assess essential processing load may not be an accurate indicator.

According to Paas (1992), perceived mental effort could also be “the total amount of controlled cognitive processing in which a subject is engaged” on a task (p. 738). The level of engagement on a task could be a reflector of generative processing. Generative processing is a reflector of learning outcomes such as accuracy (DeLeeuw & Mayer, 2008). Therefore, when measuring perceived mental effort as a way to determine cognitive load, adding a secondary measurement such as accuracy provides a more accurate determinant of essential and even generative processing loads.

According to the perceived mental effort measurement model presented by Paas and van Merrienboer (1994), there is a dimension that reflects the interaction between the task and learner characteristics on cognitive load. As previously depicted in Figure 7 of the first chapter, causal factors include the task at hand and subjects that affect cognitive load. One task characteristic is considered task complexity and a subject characteristic is prior knowledge.

*Figure 7.* Schematic representation of the causal and assessment factors that contribute to cognitive load (Paas and van Merrienboer, 1994).
The interaction between the task and subject characteristics affect cognitive load. For instance, as task complexity increases, the amount of prior knowledge a learner has could either increase or decrease the amount of cognitive load. Also depicted in Figure 7, one type of cognitive load assessment is perceived mental effort that could be measured by performance. Performance is typically considered by level of accuracy or the amount of time spent on a task. In turn, the amount of perceived mental effort expended onto a task relates to a learner’s level of cognitive load. As task complexity increases, prior knowledge affects performance and perceived mental effort, all of which may positively or negatively affect cognitive load.

Kirschner (2002) revisited Paas and van Merrienboër’s (1994a) schematic representation of cognitive load (Figure 7) and presented a third causal factor related to cognitive load – the learning environment. Because instruction is part of the learning environment, Paas, van Gog, and Sweller (2010) noted that learners could be overwhelmed from instruction that is not properly designed. If instruction fails to provide necessary guidance, learners was left to complete tasks in a way that are cognitively inefficient because there is a heavy working memory load and extraneous processing load (Kalyuga, et al., 1999). Using instruction with the modality principle has been shown to alleviate extraneous processing and make use of working memory more efficiently (Mayer, 2005b).

**Measuring cognitive load**

Perceived mental effort and performance are two measurable dimensions of cognitive load (Paas & van Merrienboër, 1993). Paas and van Merrienboër (1993) combined perceived mental effort measures and task performance as a way to assess the
efficiency of instructional conditions. As part of their conclusions, Paas and van Merrienboër (1993) noted that combining perceived mental effort and performance measurements together provides a more sensitive assessment of cognitive load than measuring perceived mental effort or performance independently. Additionally, the combined scores of perceived mental effort and performance provide a better insight to “cognitive consequences” of learning environments, which may help optimize instructional design (p. 742). Thus, Sweller, van Merrienboër and Paas (1998) claimed that measuring perceived mental effort in conjunction with performance could be the best estimator of cognitive load and instructional efficiency.

Measuring perceived mental effort could provide information that measuring only performance or cognitive load may not. In their study, Paas and van Merrienboër (1993) justified that the amount of perceived mental effort expended by learners can in fact be far more valuable to measure than other performance measures in order to get a better estimate of cognitive load. To better understand the impact of perceived mental effort as task complexity increases in this current study, perceived mental effort was assessed after each math problem on the pre- and post-tests for both the control and experiment groups.

In addition to assessing learners’ prior knowledge during the pre-test, learners’ essential processing load was assessed by measuring perceived mental effort. Typically, there are three ways to assess cognitive load: self-reports through surveys and questionnaires, measurement of heart rate, and secondary tasks. Van Gog and Paas (2008) discussed whether cognitive load should be measured during learning or a test phase depending on the category of cognitive load. Perceived mental effort should be measured while participants are working on a task. Even though many studies assess
perceived mental effort only at the end of a study, (Kalyuga, et al., 1999; Tindall-Ford, et al., 1997), Paas et al. (2003) argued that the more often cognitive load is measured, the more accurate data are attained about cognitive load, especially since cognitive load may vary during the learning process, as demonstrated in certain studies (Tabbers, et al., 2004; van Gog & Paas, 2008).

In addition to including another measurement such as perceived mental effort in conjunction with performance to ascertain cognitive load, some researchers have asked learners to rate the level of difficulty or ease in completing a task rather than asking their perceived level of expended effort (Marcus, Cooper, & Sweller, 1996). By doing so, variations in element interactivity within tasks could be better detected (Ayres, 2006). Regardless of which terminology is used, these measures were consistent in matching performance data in accordance with cognitive load theory (Moreno, 2004; van Merrienboër, Schuurman, De Croock, & Paas, 2002).

With a Cronbach’s alpha coefficient reliability of $a = 0.90$, the effectiveness of using Perceived Mental Effort Rating Scale developed by Paas (1992) to assess perceived mental effort as supported in the cognitive load theory research (Ayres, 2006; Paas & van Merrienboër, 1993, 1994a) was used in this study. Even though some research does not follow the original Perceived mental effort Rating Scale 9-point rating scale (de Jong, 2010; Gerjets, Scheiter, & Catrambone, 2004; Kalyuga, et al., 1999; Moreno, 2004; Moreno & Valdez, in press; Swaak & de Jong, 2001), the 9-point response options are most frequently used (Paas, Tuovinen, et al.; Paas & van Merrienboër). The original 9-point scale was used in this study by asking participants to rate their perceived mental effort on the scale from 1 (very, very low perceived mental effort) to 9 (very, very high
perceived mental effort).

Sriraman (2003) noted that a potential limitation in his study was that student motivation to participate in the study might have positively influenced students’ levels of effort, thus providing skewed results. Even though participant participation is voluntary in this current study, such a self-selection bias may also occur because there is a clause stated in the potential participant consent cover letter indicating that participants will not be allowed to work on other studies, use technology of any kind, or leave the classroom for the duration of the study.

Performance is typically measured in terms of accuracy and time on task. For instance, instructional manipulations meant to change perceived mental effort such as those presented through problem-solving tasks that are graduated in complexity may only be effective if learners are willing to invest the necessary perceived mental effort (Paas & van Merrienboër, 1993). For instance, two learners may produce similar performance results, but the level of effort that each learner had to exude may significantly differ. With regard to this current study, generative processing load was measured by performance accuracy.

DeLeeuw and Mayer (2008) observed that the understanding of how to measure cognitive load is a “fundamental challenge” for the theory itself (p. 223). They stressed that different measurements of cognitive load should not be assumed as accurate indicators of overall cognitive load. Each load should be measured independently. Thus, DeLeeuw and Mayer explored three different measurements to assess each of the three types of cognitive load: essential, extraneous, and generative in a multimedia setting for participants with low prior knowledge, similar to that of the anticipated level of prior
knowledge for the nursing student population in this current study. Even though there is a multitude of ways to measure cognitive load, DeLeeuw and Mayer implicated measurements in line with previous studies. DeLeeuw and Mayer measured response time as an indicator for extraneous processing. Because response time will not be measured in this current study, the DeLeeuw and Mayer findings regarding essential and generative processing are most pertinent.

In their study, DeLeeuw and Mayer (2008) manipulated the essential processing load by varying the levels of complexity in the task. High-complexity was considered to have many interacting concepts whereas low-complexity involved few interacting concepts. In line with Paas and van Merrienboer (1994a), DeLeeuw and Mayer considered that participants should rate perceived mental effort significantly higher at points that are highly complex compared to a lower perceived mental effort rating on low complexity points in a task. A self-reported perceived mental effort rating was administered multiple times during the study in line with the Paas et al. (2003) argument. Results indicated that perceived mental effort was most related to essential processing. In relation to this current study, perceived mental effort was assessed through self-reports after each mathematical problem to better gauge participants’ immediate perceptions of perceived mental effort as a way to measure essential processing.

DeLeeuw and Mayer considered low-level performance from the participants who engaged in less generative processing during learning. Participants with higher performance ratings were thought to have engaged in higher generative processing during learning. The post-test in this current study is a way to measure generative processing. DeLeeuw and Mayer coded their final assessment by allocating one point for each correct
answer similar to the post-test in this current study and similarly, there was only one possible correct answer despite multiple ways of reaching the answer.

Comparable to Paas and van Merrienboër (1994a), a condition that DeLeeuw and Mayer considered was that the participants who scored low on the performance assessment should have rated their perceived mental effort significantly higher overall than the participants who scored high. Conversely, a high perceived mental effort rating could indicate more generative processing that could lead to high performance. DeLeeuw and Mayer reported no significant correlations between perceived mental effort and accuracy.

**Modality Principle**

The modality principle comes from Mayer’s cognitive theory of multimedia learning. The instructional format simultaneously presents narrated text and dynamic images. Dynamic images refer to images that move in some way. Using animation and slideshows are ways to include dynamic images. In this study, a real-time recording of handwriting numerical sequences is considered a dynamic image. Essentially, a modality effect can occur when instructional material presented in simultaneous audio and visual format is superior to visual-only instruction (Kalyuga, et al., 1999; Leahy, Chandler, & Sweller, 2003; Mayer & Moreno, 1998; Moreno & Mayer, 1999a, 1999b; Tindall-Ford, et al., 1997). To obtain a modality effect, two or more sources of information must not only refer to each other, but also be processed together (Kalyuga, Chandler, & Sweller, 2004; Low & Sweller, 2005).

One study that Mayer and Moreno conducted using the modality principle included instruction on car brakes (1998). In one treatment, participants read text about
the mechanics of car brakes and were required to refer to visual images depicting the text. This treatment forced the participants to split their visual attention between text and picture, and picture to animation. Another treatment integrated the modality principle by converting the text to narration. Participants in the modality principle treatment were able to maintain focus on the visual model while listening to the narration, thus offloading the cognitive processing from only the visual channel to both channels. The results demonstrated an effect size of 0.78 in favor for instruction integrated with the modality principle. In the same study, Mayer conducted similar treatments but with content related to lightning. Effect sizes in the lightning experiment resulted in 1.49, again in favor for the modality principle.

Ginns (2005) conducted a modality principle meta-analysis within which a limited selection of two studies emphasized geometry (Jeung, et al., 1997; Mousavi, et al., 1995) and one study focused on algebra (Atkinson, 2002). Even more limiting when reviewing the effects of the modality principle on mathematics, both of the geometry studies only measured speed as a performance measurement. Because speed is not a focus in this study, Jeung et al.’s and Mousavi et al.’s studies will not be reviewed despite the positive implications each study had on working memory.

Leahy and Sweller (2011) conducted two experiments with a focus on length of instruction. The first experiment consisted of few slides that required a longer period of time to explain each slide where as the second experiment consisted of more slides requiring a shorter period of time to explain each slide. Essentially, Leahy and Sweller broke down the longer slides from the first experiment into more and shorter slides for the second experiment. The amount of information was the same between Leahy and
Sweller’s two experiments; the information was simply distributed in different lengths between the experiments. This occurs not necessarily because there is more overall information to explain, but that there is more information on each slide to explain. Their results indicated that participants performed better on few slides that lasted longer periods of time. Based on their results, there were fewer slides of information that lasted longer with regard to this current study.

Learning environments that include algebra are considered to range in complexity levels because solving the problems could require multiple steps (Mayer, 1985). In the interest of this study, the one viable study to explore from the Ginns meta-analysis was conducted by Atkinson (2002). Atkinson examined five learning environments in an algebra setting: text and static visual, text only, narration only, text and dynamic visual, and narration and dynamic visual. Like DeLeeuw and Mayer (2008), Atkinson measured accuracy as a way to determine learning outcomes in a modality principle setting. Where difficulty ratings were considered reflective of accuracy for DeLeeuw and Mayer, Atkinson considered difficulty as a perceived level of effort allocated for that task. Participants’ perceived level of task difficulty was lowest with the instruction that presented narration and dynamic visual – in other words, the modality principle with an effect size of 1.60. In the same experiment, participants’ learning outcomes in the modality principle learning environment were statistically superior to the other four environments with effect sizes of 1.04 on near transfer tests and 1.06 on far transfer tests.

It is of interest in this study to present participants with math problems that range in complexity to better gauge where the modality principle has benefits, and where it may have shortfalls (Mayer, 2009).
**Schema.** Students with low schema tend to demonstrate stronger effects from instruction with multimedia than students who possessed high levels of schema (Mayer & Moreno, 1998). Research investigating the effects of the modality principle during mathematical tasks has found benefits for learners who measure at lower levels of schema (Mayer, 2001). Seufert, Schutze, and Brünken (2009) observed that the modality effect was confirmed for less-skilled learners compared to those with more experience. According to a cognitive theory of multimedia learning, students with high schema may be able to generate their own mental images while listening to an animation or reading a verbal text so having a contiguous visual presentation is not needed.

**Working memory capacity.** Learners have a limited working memory, and instructional representations should be designed with the goal of reducing unnecessary cognitive load. Beckmann (2010) made the distinction that the modality principle does not necessarily decrease cognitive load, but that by utilizing both the visual and verbal cognitive channels, limited working memory capacity is enhanced, thus resulting in better performance outcomes. Beckmann’s argument supports this current study because the intent here is to not measure or decrease cognitive load, but to measure the difference in working memory capacity while performing mathematical problem-solving tasks at higher levels of capacity. It is thought that a modality effect would be more apparent on tasks as complexity increases (Beckmann, 2010).

In a study comparing instructional materials between narration and dynamic visuals vs. visual text and static visuals, Tindall-Ford, Chandler and Sweller (1997) replicated Mousavi, Low and Sweller’s study. Tindall-Ford and colleagues suggested that instruction using the modality principle might have positively contributed to the
effectiveness of working memory. Interestingly, Tindall-Ford, Chandler and Sweller observed a modality effect only when highly complex materials were presented. Thus was the case for 41 out of 43 studies investigating the effects of the modality principle (Ginns, 2005); however, we do not know specifically at which level of complexity the modality principle has an effect on accuracy and perceived mental effort.

Accuracy and modality principle. Much of the empirical evidence supporting the modality principle relates to knowledge acquisition. For example, students viewing an audiovisual presentation through the modality principle outperformed students receiving a visual-only presentation (Kalyuga, et al., 1999). Moreover, a series of studies performed by Mayer and his colleagues (Mayer & Anderson, 1991; Mayer & Moreno, 2002) suggested that students receiving animations with narration outperformed students viewing the same animation with on-screen text in recall and problem-solving transfer tests. For the purpose of this current study, it is hypothesized that accuracy may decrease as complexity increases, but that accuracy was higher in the experiment group receiving instruction using the modality principle compared to the control group receiving visual-only instruction.

Perceived mental effort and modality principle. As task complexity increases, DeLeeuw and Mayer (2008) and Paas and van Merrienboër (1994a) hypothesized that perceived mental effort would in turn increase. If instruction fails to provide necessary guidance, learners was left to complete tasks in a way that are cognitively inefficient because there is a heavy cognitive load (Kalyuga, et al., 1999), specifically extraneous processing. When extraneous processing is overloaded, less room is left for essential processing to take place, thus leading to higher perceived mental effort ratings. Even
though perceived mental effort still increases as complexity increases when instruction is presented in the modality principle format, participants do not rate perceived mental effort as high as during non-modality principle learning environments. The implication is that instructional material is balanced between both working memory channels for more efficient cognitive processing. With regard to this current study, it is hypothesized that perceived mental effort ratings will increase as complexity increases, but that perceived mental effort will still be lower in the experimental group receiving instruction using the modality principle versus the control group receiving visual-only instruction.

**Nursing and Math Education**

Despite the emphasis on needing math skills, there is a lack of research describing how math is taught to nursing students other than what is considered to be traditional by way of lecture or textbook. Harrell provided suggestions as to how nursing students can go about improving their math skills (1987). For instance, because no significant findings were demonstrated between nursing students who received a formal math course versus students who did not, Harrell suggested that formal math courses should not be required but that nursing students should nonetheless practice math. Additionally, Harrell suggested that attention should be given to math scores of entering nursing students because prior performance would help predict future performance. Typically, nursing students are instructed to seek out math textbooks designed specifically with medical mathematics. In one anecdotal letter to incoming nursing students, the nursing faculty at one community college stressed that the key to math success is practice, similar to Harrell’s suggestion. It is unclear, though, as to how that practice should come about.

Costello (2010) compared three teaching strategies for undergraduate nursing
students when learning math: computerized instruction and simulation laboratory work together, computerized instruction only, and simulation instruction only. A traditional instructional environment served as the control and consisted of nine hours of general medication mathematical instruction consisting of combined lecture and lab time. It is not clear if the three strategies also consisted of nine hours of instruction. In each of the instructional settings, Costello’s math problems increased in complexity and students were instructed to reflect on previous math teachings in middle school or high school. Repeated measures were taken at four points: a pre-test, immediate post-test, one month, and six months after receiving a respective form of instruction. Costello found that students who received computer and simulation instruction outperformed not only the other experimental instructional designs, but also the traditional lecture instructional format at all points of measurement, especially on the immediate post-test assessment.

It is not clear how Costello approached the theoretical balance of verbal and visual balance. However, considering that the traditional instruction in Costello’s study included verbal-only presentation, it seems as though the other instructional designs included some form of visual information, thus off-loading the cognitive load. With this in mind, Costello’s results were to be expected. Costello’s results lend further support to designing instruction with a balance of visual and verbal information through the modality principle because of cognitive off-loading.

Other studies conducted by Pappas and Allen (1999) and Cosler (1974) suggest that providing individualized instruction can help increase math skills for undergraduate nursing students. Pappas and Allen, for instance, conducted a four-year study by identifying mathematical at-risk entry-level nursing students through a math examination
and then allowing for individual clinical faculty members to customize math teaching and learning for those students. Results indicated successful rates in math competencies for students who were first identified as at-risk. Cosler (1974), on the other hand, did not specifically conduct a study but rather designed individualized math problems for a variety of specific math content areas related to numerous fields one of which being nursing.

Providing individualized instruction as Pappas and Allen (1999) and Cosler (1974) suggest designing instruction with computer or simulated settings as Costello (2010) indicated would enhance undergraduate nursing student math skills. Costello’s study lends a basis for the control group as a traditional instructional setting using one form of presentation for the purpose of this current study. In this case, visual-only instruction was provided to the control group whereas Costello used verbal-only. The experiment group in this current study will receive instruction that balances instruction between visual and verbal forms of presentation, similar to that of Costello’s study.

**Variables grounded in Literature**

This current study stemmed from a study conducted by Halford, Baker, McCradden, & Bain (2005). On a group of 30 participants, Halford et al. examined the effects on working memory capacity by measuring accuracy as task complexity increased. Participants included of a mixture of faculty, staff, and university students in math and psychology. The researchers believed that the more expertise a learner had in a given field, the more schema that learner has to rely upon. Halford et al.’s descriptive study exposed the participants to a series of tasks that increased in complexity.

In Halford et al.’s study, a McNemar change test indicated that accuracy
significantly decreased as complexity increased ($X^2 (1, N=30) = 6.25, p < 0.02$). This finding was in line with previous studies (Cowan, 2000, 2005; Halford, et al., 1998; Luck & Vogel, 1997). Another finding was that more time was spent on tasks as complexity increased ($d = 0.68$).

Twenty-two of the original 30 participants were available for the second experiment. Participants were required to interpret a graphic representation with five-element interaction. The results extended the findings from the first experiment in that the more complex the task, the more accuracy decreased.

Halford et al. concluded that the results are based on cognitive processing loads. In this case, cognitive processing was affected by the limitations of working memory capacity. Implications from this result indicate that strategies for reasoning and decision-making can entail processing of no more than four elements in any one cognitive step. These findings are in line with previous studies (Cowan, 2000; Luck & Vogel, 1997). A way to overcome the working memory capacity limitation is to gain knowledge of higher-order elements, but the underlying cognitive processes correspond to a maximum of about four elements.

A limitation in Halford et al.’s study is that the researchers assumed that because accuracy decreased and more time was spent on task as complexity increased that perceived mental effort and working memory were affected; however, the authors did not explicitly measure this assumption. Paas et al. (2003) pointed out that the more often cognitive load is measured, the more accurate the view of the actual cognitive load is, especially since cognitive load may vary during the learning process, as demonstrated in certain studies (Paas, Tuovinen, et al., 2003; Tabbers, et al., 2004; van Gog, Paas, & van...
Merrienboër, 2004). Kalyuga, Renkl, and Paas (2010), suggested that researchers need to examine limited cognitive architecture such as working memory and cognitive load in order to better problem solve. Additionally, having pre-existing schema in Halford et al.’s study did not improve performance as Mayer (1985) would have predicted.

Halford et al.’s findings leave to question whether working memory capacity is the focus in successfully and authentically completing problem-solving tasks with high task complexity rather than having an established relationship between the task at hand and schema. This current study will add to Halford et al.’s descriptive findings because the suggested approach is experimental in comparing two different instructional designs with the intention of alleviating the negative workings of cognitive processes while enhancing performance.

Gaps in the Literature

Sweller’s (1994) cognitive load theory, Miller’s (1956) in addition to Baddeley and Hitch’s (1974) research in working memory, and Paivio’s (1986) dual-coding theory provide the foundation for Mayer’s (2001) cognitive theory of multimedia learning. With these theories in mind, there are clear links made in the literature among variables such as long-term memory, perceived mental effort and accuracy, and working memory capacity and perceived mental effort and accuracy (Paas & van Merrienboër, 1993; Sweller, van Merrienboër, & Paas, 1998). There are also connections made between the modality principle and perceived mental effort (DeLeeuw & Mayer, 2008; Paas & van Merrienboër, 1994) and accuracy (Kalyuga, et al., 1999; Mayer & Anderson, 1991; Mayer & Moreno, 2002).

Even though the modality principle has demonstrated positive learning outcomes
when tasks are complex (Ginns, 2005; Mayer, 2009), Mayer presents a potential limitation to the study of the modality principle. There is a lack of research exploring the modality principle at varying levels of task complexity. Understanding the limitations of the modality principle in this manner may provide additional information as to what level of complexity the instructional format may prove better learning outcomes regarding accuracy and perceived mental effort.

It is more effective to measure cognitive load when assessing accuracy and perceived mental effort together (Paas & van Merrienboër, 1994). By doing so, this study provided an extension to Halford et al.’s (2005) study. Halford and his colleagues examined the impact of visual-only instruction at varying levels of task complexity on accuracy and perceived mental effort in a descriptive study. Results indicated that as task complexity increased, accuracy decreased and perceived mental effort increased. The idea with this current study was to take the descriptive results and adapt two different instructional methods. One type of instruction would be in line with Halford et al.’s 2005 study of visual-only material. The other type of instruction would balance information on both visual and verbal working memory channels through Mayer’s (2009) modality principle. Mayer’s suggested limitation and Halford et al.’s study provide the basis for this current study of comparing the effects between visual-only instruction and modality principle instruction on accuracy and perceived mental effort at different levels of task complexity.
CHAPTER III

METHODOLOGY

The purpose of this study was to compare the effects of two instructional formats on math accuracy and perceived mental effort as indicated by a post-assessment. Participants included 48 undergraduate nursing students spanning two northern California universities who completed a series of math problems across three levels of complexity: low, moderate, and high. The independent variable was based on two levels: experimental instruction and control instruction. One group (n = 26) of participants received an experimental form of instruction using the guidelines of the modality principle (Mayer, 2009), and one group (n = 22) received a traditional form of instruction using visual-only materials (Costello, 2010; Halford et al., 2005). The dependent variables were accuracy and perceived mental effort. Accuracy was measured by correct and incorrect answers. Measuring perceived mental effort on a Likert-scale ranging from 1 (very, very low mental effort) to 9 (very, very high mental effort) in addition to accuracy provided a stronger indicator of cognitive load because not only is performance assessed but also the mechanics of the cognitive load processes (Paas & van Merrienboër, 1994). The quasi-experimental research design is described in more detail within this chapter including the following: the independent and dependent variables, sample selection including USF IRBPHS considerations, the proposed instrumentation and procedures, and a description of the data analysis.

Research Questions

There were two research questions that guided this study. The questions were formulated based on the notion on examining the outcomes on the post-assessment for
each group after receiving the respective form of instruction. The research questions that guided this study were:

1. Does instruction using the modality principle result in better accuracy as compared to visual-only instruction at each level of complexity as indicated by post-assessments?

2. Does instruction using the modality principle result in lower perceived mental effort when compared to visual-only instruction at each level of complexity as indicated by post-assessments?

It was hypothesized that first, the experimental group would demonstrate better accuracy at each level of complexity on the post-assessment as compared to the control group and second, that the experimental group would rate lower perceived mental effort at each level of complexity on the post-assessment as compared to the control group.

**Research Design**

A quasi-experimental research design was used in this study to compare two different instructional design formats on accuracy and perceived mental effort at three different levels of task complexity: low, moderate, and high. The first instructional design was based on the modality principle and the second design was presented in a visual-only format. When a true randomized-selection process for gathering participants is not possible, quasi-experimental designs are used (Trochim, 2006). This specific type of research design is used because dependent variables were measured without a random participant pre-selection process. For instance, the participants were already part of a classroom setting and the division of participants into either the control or experiment group was convenient. Once the participants...
were divided into either a control or experimental group, the current study would follow similarly to any other experiment where there is a treatment and some form of measurement that is compared between the different groups. Quasi-experimental designs reduce the time and resources needed for any experimentation because the sample population is pre-determined (Trochim, 2006).

Using a quasi-experimental design in a social science research setting such as the one in this study can be advantageous because the generated results can be useful for allowing some generalizations about trends in a given field or topic. Alternatively, one disadvantage to quasi-experimental designs is the absence of total randomization, thus potentially leading to ineffective statistical tests (Trochim, 2006). This study, however, is quantitative in nature and, thus, the statistical analyses strengthened the generated results and minimized threats to external validity that may occur with a full experimental design.

**Independent Variable**

The independent variable was the type of instructional design on two levels: experimental and control. The experimental group received instruction designed under the guidelines of the modality principle (Mayer, 2009). This group was coded at 1. The modality principle guidelines indicate that learning material contributes to meaningful learning if presented in a simultaneous audio and visual format to offload the cognitive impediments of using only one working memory channel. Moreover, the audio portion is meant to take the place of any text in the learning material. For this current study, the experimental instruction included a real-time recording of worked-out algebraic math examples (Sweller, 1999) with a simultaneous narration.
explaining the process (Chi et al. 1994).

Visual-only instruction containing textual narration and worked-out examples was provided for the control group. This group was coded as 0. The control group received instruction designed with all text. Halford, Baker, McCready, and Bain’s (2005) study and Costello’s (2010) study lent a basis for the control group as a traditional instructional setting because of the results garnered when using one mode to present learning material. Halford et al. specifically examined accuracy as complexity levels increased and presented participants with visual-only material and noted that as complexity increased, accuracy decreased. Moreover, Halford et al. suggested that accuracy decreased because working memory was overloaded by the use of only one channel via the visual-only instruction; however, there was no explicit measurement for this. Costello demonstrated that instruction designed in only one format, either visual or verbal, tends to cause a detriment for learning mathematics in an undergraduate nursing course.

It was of interest in this current study to compare accuracy outcomes between visual-only instruction and instruction presented in a format that was balanced between visual and verbal information. Thus, it was also of interest in this current study to explicitly examine and compare the outcomes of cognitive overload by measuring perceived mental effort between both forms of instruction (Paas, 1992).

**Dependent Variables**

The dependent variables were accuracy and perceived mental effort, which were measured during the pre- and post-assessments. Accuracy was coded for 0 = incorrect and 1 = correct. Because levels of essential processing are affected by prior
knowledge (Sweller, 1988), a subjective measure of perceived mental effort was assessed through the Perceived Mental Effort Rating Scale (Paas, 1992). The Perceived Mental Effort Rating Scale was introduced by Paas (1992) and subsequently applied by Paas and van Merrienboër (1993, 1994a) (Appendix E). Participants assigned a definitive number to the level of perceived mental effort on a 9-point Likert scale where 1 = very, very low perceived mental effort and 9 = very, very high perceived mental effort (Paas, 1992, p. 430) after each item.

Self-reporting is one of the most frequently used methods to measure cognitive load (Paas, Tuovinen, et al., 2003). The perceived mental effort assessment was administered during the pre- and post-assessments after every math problem and both the control and experiment groups rated their perceived mental efforts. The perceived mental effort assessment provided further information about the cognitive processes during math problem solving and how to better design instruction to alleviate cognitive load during tasks with varying levels of complexity.

**Participants**

There were 48 participants from two Northern California undergraduate schools of nursing. Participants were randomly assigned to be part of either the control group (n = 22) or the experimental group (n = 26). It was not possible to recruit all participants in person; thus, some participants were contacted during class time and via e-mail. Regardless, participant consent was collected prior to conducting the study. Moreover, there were numerous scheduling conflicts. Thus, the study was conducted over several meetings so that volunteers could attend. Participants were as equally distributed between the control and experimental groups as possible to ensure a balance of ability.
This was particularly critical because participants were enrolled across two universities. Participants were not financially reimbursed, nor did students receive course credit for volunteering.

**Protection of Human Subjects**

An application was submitted to the USF IRBPHS for approval to gain permission to conduct the study including the pilot study and expert review panel. Access to an undergraduate nursing study population was granted from two northern California universities’ School of Nursing programs. Participants read, agreed to, and signed a consent letter that informs them of the study, specifically that confidentiality would be upheld and that the work completed was in no way to influence their course grade or status.

**Timeline**

In order to better represent the timeline for this study, Table 2 presents the overview of when this study was conducted. After receiving IRBPHS approval from the University of San Francisco, both the pilot study and expert review panel took place during the fall semester of 2011 in September. After the data were analyzed from the pilot study (Appendix A), instruction using modality principle guidelines was designed for the expert panel to review (Appendix B) in November of 2011. After feedback from the panel was received of the same month and year, the instruction and the instrumentation were revised. The main study was conducted during the spring 2012 semester between January and March.
Table 2

*Timeline Overview of Study*

<table>
<thead>
<tr>
<th>Time</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>September 2011</td>
<td>Pilot of Assessment Instruments</td>
</tr>
<tr>
<td>October 2011</td>
<td>Design of Instruction</td>
</tr>
<tr>
<td>November 2011</td>
<td>Recording of Instruction</td>
</tr>
<tr>
<td>November 2011</td>
<td>Expert Review</td>
</tr>
<tr>
<td>November 2011</td>
<td>Revision of Experimental Instruction</td>
</tr>
<tr>
<td>January-March 2012</td>
<td>Main Study</td>
</tr>
</tbody>
</table>

The study itself lasted 53 consecutive minutes. After receiving a brief introduction, all participants regardless of control or experimental group completed a pre-assessment (Appendix C), received their respective control or treatment formats of instruction, and a post-assessment (Appendix D). The pre- and post-assessments included 15 math problems in addition to a perceived mental effort rating which used a Likert-type scale (Appendix E).

**Instrumentation**

In order to better design the study, the assessment instruments were piloted and an expert review of the instruction was conducted. The results of the assessment pilot and expert review panel are presented first in this section prior to presenting information for the main study.

**Math Knowledge Assessment**

The math problems in the assessment included mixed numbers that have been found to be difficult for learners (Brown, 2006). For instance, Table 1 as previously
provided in Chapter 1 reiterates Brown’s breakdown of the types of problems for which accuracy was lowest. Such items include decimals, fractions, and percentages.

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Item</th>
<th>Student Responses in 1988 (%)</th>
<th>Student Responses in 2003 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3 ½ - 1 2/3</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>2</td>
<td>1 5/7 * 2 1/3</td>
<td>63</td>
<td>57</td>
</tr>
<tr>
<td>3</td>
<td>10/105</td>
<td>58</td>
<td>67</td>
</tr>
<tr>
<td>4</td>
<td>6 yd 1 ft 9 in – 2 yd 2 ft 10 in</td>
<td>56</td>
<td>58</td>
</tr>
<tr>
<td>5</td>
<td>880 / 0.8</td>
<td>55</td>
<td>60</td>
</tr>
<tr>
<td>6</td>
<td>1/200 change to decimal</td>
<td>43</td>
<td>42</td>
</tr>
<tr>
<td>7</td>
<td>1.6 change to fraction</td>
<td>40</td>
<td>65</td>
</tr>
<tr>
<td>8</td>
<td>2 1/3 / 1 ½</td>
<td>38</td>
<td>52</td>
</tr>
</tbody>
</table>

Brown also indicated that conversions from fractions to decimals and vice-versa measured at low performing rates.

Depending on the equation, in this study, certain items may have been cross-categorized similar to that of Brown (2006). For instance, Brown’s Item 7 in Table 1 asks to convert a decimal to a fraction. Specifically in this current study, Item 14 in Table 3, for example, first needs to be solved in decimal format and then converted to a percent. These types of cross-category items may differ in complexity based on the number of potential steps it could take to solve a problem. The difference between the anticipated levels of complexity noted in Table 3 indicates not just the anticipatory...
number of steps taken to solve the problems, but also that each subsequent category builds upon the previous category (Sweller & Chandler, 1994). For instance, the decimals category includes equations only related to decimals meaning that the decimals category is thought to be the easiest category of all three. The percentages category includes not only percentages but also decimals meaning that this category is believed to be of moderate complexity. The fractions category includes all three: decimals, fractions, and percentages meaning that this category is possibly the most complex.

Taking this information into consideration, the pre- and post-assessment items were designed with the anticipated range from low to high complexity and using items similar to that of Brown. Of the six decimal problems, three were predicted to be low in complexity, two of moderate complexity, and one of high complexity. Of the five percent problems, two were predicted to be of low complexity, one of moderate complexity, and two of high complexity. Lastly, of the seven fraction problems, one was predicted to be of low complexity, three of moderate complexity, and three of high complexity. The anticipatory breakdown of item complexity for each category is presented in Table 3.

Item 1 is an example of what was an anticipated low complexity decimals problem because “What is 1.67 of 75?” is a simple process of division. Item 10 asked participants to “Convert 1.67 into a fraction,” which was anticipated to be moderate in complexity because of the conversion process. The example of Item 14 “If you are to administer 6.95 mls for the first hour and 7.61 mls each hour after, by what percent do you increase the dosage” was anticipated to be a high complexity problem because it required to solve for the decimals first and then convert that answer into a fraction in
perhaps more than one step. The percentages category required learners to code-switch in that decimals need to be converted into percentages, and vice-versa, thus adding to the complexity level of the percentages category. The fractions category was the most general and abstract because it would contain any combination of decimals, percentages, and fractions and, thus, be anticipated to be most difficult. An example of what was an anticipated high complexity item was Item 16 that prompted “The patient’s chart reads that you are to administer 1 3/40 liters of saline for every 50% of antibiotics. If only 0.20 of the 50% of antibiotics has been administered, how many liters of saline do you provide?”
### Anticipatory Breakdown of Problems, Categories, and Levels of Complexity Prior to Pilot Study

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Problem</th>
<th>Category</th>
<th>Anticipated Level of Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.67 of 75</td>
<td>Decimals</td>
<td>Low</td>
</tr>
<tr>
<td>2</td>
<td>0.87 of 94</td>
<td>Decimals</td>
<td>Low</td>
</tr>
<tr>
<td>3</td>
<td>0.45 of 135</td>
<td>Decimals</td>
<td>Low</td>
</tr>
<tr>
<td>4</td>
<td>35% of 80</td>
<td>Percentages</td>
<td>Low</td>
</tr>
<tr>
<td>5</td>
<td>9 is what % of 45</td>
<td>Percentages</td>
<td>Low</td>
</tr>
<tr>
<td>6</td>
<td>2/5 of 360</td>
<td>Fractions</td>
<td>Low</td>
</tr>
<tr>
<td>7</td>
<td>3.2x + 45 = 6.4</td>
<td>Decimals</td>
<td>Moderate</td>
</tr>
<tr>
<td>8</td>
<td>34.5 – 6.8x = 45x + 19.81</td>
<td>Decimals</td>
<td>Moderate</td>
</tr>
<tr>
<td>9</td>
<td>You have seen 16 of your 20 patients. What percent remains?</td>
<td>Percentages</td>
<td>Moderate</td>
</tr>
<tr>
<td>10</td>
<td>1.67 as a fraction</td>
<td>Fractions</td>
<td>Moderate</td>
</tr>
<tr>
<td>11</td>
<td>12.5% as a fraction</td>
<td>Fractions</td>
<td>Moderate</td>
</tr>
<tr>
<td>12</td>
<td>56% as a fraction</td>
<td>Fractions</td>
<td>Moderate</td>
</tr>
<tr>
<td>13</td>
<td>4.5 – 7.2x = 3.4x – 49.5 + 12.3</td>
<td>Decimals</td>
<td>High</td>
</tr>
<tr>
<td>14</td>
<td>A patient’s chart reads that you are to administer 6.95 mls for the 1st hour and 7.61 mls each hour after. By what percent to you increase the dosage?</td>
<td>Percentages</td>
<td>High</td>
</tr>
<tr>
<td>15</td>
<td>65% of 2000 calories is needed for a 110 pound person. Your patient weighs 76 pounds. What percent of 2000 calories is needed?</td>
<td>Percentages</td>
<td>High</td>
</tr>
<tr>
<td>16</td>
<td>You are to administer 1 3/4 liters of fluid in 30 minutes. How many liters in 96 minutes?</td>
<td>Fractions</td>
<td>High</td>
</tr>
<tr>
<td>17</td>
<td>If a person weighs in at 72 kilograms that converts to approximately 159.3 lbs., how many kilograms in 540 lbs.?</td>
<td>Fractions</td>
<td>High</td>
</tr>
<tr>
<td>18</td>
<td>You are preparing to administer 1 5/7 mg of antibiotics for every 2 1/3 mg of saline. How many mg of antibiotics will you administer for 18 2/3 of saline?</td>
<td>Fractions</td>
<td>High</td>
</tr>
</tbody>
</table>
Perceived Mental Effort Assessment. Because levels of essential processing are affected by prior knowledge (Sweller, 1988), a subjective measure of perceived mental effort was assessed through the Perceived Mental Effort Rating Scale (MERS) (Paas, 1992). Because of its wide acceptance and use, the scale was not piloted as part of the assessment instrument. MERS was administered during the pre- and post-assessments after every math problem and both the control and experiment groups rated their perceived mental efforts. Self-reporting is one of the most frequently used methods to measure cognitive load (Paas, Tuovinen, et al., 2003). MERS was introduced by Paas (1992) and subsequently applied by Paas and van Merrienboër (1993, 1994a) (Appendix E). Participants assigned a definitive number to the level of perceived mental effort on a 9-point Likert scale where 1 = very, very low perceived mental effort and 9 = very, very high perceived mental effort (Paas, 1992, p. 430). This scale provided further information about the cognitive processes during math problem solving and how to better design instruction to alleviate cognitive load during tasks with varying levels of complexity.

The higher the number indicated the more mental effort was exerted during the mathematical problem solving process. The reverse occurred if there was a low mental effort rating. It was thought that the pre-assessment would demonstrate higher levels of mental effort whereas the post-assessment would show a decrease of mental effort after having received either forms of instruction. Furthermore, it was hypothesized that the experimental group receiving the multimedia format of instruction would result in even lower mental effort than the control group.
Pilot of Assessment Instrument

The pilot study served three purposes, all of which were meant to provide a deeper understanding of how to better design instruction using the modality principle. First, the pilot provided a better estimate of participant math ability to design the study and second, it was meant to better gauge the actual amount of time needed for the main study. The third purpose was to establish the number of complexity levels among the 18 math problems.

The pilot study included a packet of 18 mathematical problems that fell into one of three categories: decimals (six problems), percentages (five problems), and fractions (seven problems) (Appendix A), which took place during the fall semester with 17 participants (n = 15 females) who were enrolled in their first semester of their second year of a nursing program at a northern California university. It was determined that participants in the pilot study would be compensated for their time with a light breakfast because the participants gathered 30 minutes prior to their 8 AM morning class. Second-year nursing students were recruited for the pilot study because the sample was most representative of the population for the main study. The pilot study lasted for 30 minutes: 10 minutes for the breakfast and explanation of the procedures and 20 minutes for the pilot study itself. A maximum of 20 minutes for the pilot test is justified because previous studies use 20-minute timed sessions for assessments (Park, Moreno, Seufert, & Brünken, 2010).

Even though the main study was to include 15 math problems, the additional three problems in the pilot provided more leeway to re-evaluation problem design if needed. Participants were allowed to use calculators; however, they were expected to demonstrate
by hand the steps they took to solve each problem. Directions were located at the beginning of the packet and then a prompt reading “solve for x” for each problem at the top of each page.

**Pilot of assessment instrument results.** To answer the first reason for the pilot, the study was set with a time limit of 20 minutes to complete the packet of 18 math problems, all of which ranged in levels of complexity. If the participants finished in less than the 20-minute time limit, then the main study would be set at the time of the last participant to finish. In this case, the first student finished at 11 minutes 28 seconds. Even though many of the participants finished in less than 20 minutes, four participants still had the packet when time was called. It was not clear if the remaining four participants did not complete the packet or were simply reviewing their answers. After evaluating the work, three of the four students had completed the packet in its entirety and the fourth was working on the final problem without having finished it. Thus, the results indicated that the participants for the main study would receive the 20-minute time limit.

The second purpose to the pilot was to better determine the participants’ math ability in accordance to prior research and to better determine the design of the instrumentation needed for the main study. Participants in this pilot study demonstrated low performance on problems including decimals, percentages, and fractions in line with Brown’s (2006) study and confirmed such prior research (Elliot and Joyce, 2004; Gillham and Chu, 1995). As depicted in Table 3, participants demonstrated low performance in conversions from decimals and percentages into fractions in addition to
problems including percentages. Low performance was determined based on scoring 70% or less just as in Brown’s study.

Finally, the third purpose for the pilot was to better establish the number of levels of complexity that would be used during the main study. There was an anticipation of three to five levels of complexity that this pilot was to confirm. It was anticipated that each math category of decimals, percentages, and fractions would range in difficulty. The pilot study helped determine the number of levels of complexity for the math problems overall and the complexity levels within each category.

The results indicated that there were three distinct levels of complexity as shown in Table 4. The complexity levels were determined by the percent of correctly answered problems. The problems that were answered incorrectly 70% or less were considered high complexity in accordance to Brown’s (2006) study that indicated 70% and below is failing. Items that were answered correct 71-79% were considered moderately complex and 80% and above were considered low in complexity. Even though there was some difference in complexity levels within each category, there was not enough variation to solidify a strong representation of the amount of items that varied in complexity within each category. Therefore, the main study considered complexity across the entire category rather than differentiating complexity levels within each category. Having an understanding of where students made mistakes facilitated the design of instruction that helps resolve future mistakes of the same kind. This overall information confirmed the design of instrumentation for the main study.
## Table 4

**Established Breakdown of Problems, Categories, and Levels of Complexity After Pilot Study**

<table>
<thead>
<tr>
<th>Item Number</th>
<th>Equation</th>
<th>Category</th>
<th>Anticipated Level of Complexity</th>
<th>Actual Level of Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.67 of 75</td>
<td>Decimals</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>2</td>
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<td>High</td>
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<td>14</td>
<td>A patient’s chart reads that you are to administer 6.95 mls for the 1st hour and 7.61 mls each hour after. By what percent to you increase the dosage?</td>
<td>Percentages</td>
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<td>High</td>
</tr>
<tr>
<td>15</td>
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<td>Low</td>
</tr>
</tbody>
</table>
You are preparing to administer 1 5/7 mg of antibiotics for every 2 1/3 mg of saline. How many mg of antibiotics will you administer for 18 2/3 of saline?

As a result of the pilot study, Items 1, 13, and 16 were not included in the assessment instrument used in the main study to better balance the three levels of complexity among the remaining items. Because we already know that the modality principle results in positive outcomes for math problems of high complexity, there was a need to have more items of moderate and low level of complexity. By omitting three problems, there were 7 problems at the low level of complexity, 4 problems at the moderate level of complexity, and 4 problems at the high level of complexity.

**Expert Review**

Based on the information gathered from the pilot of the assessment instrument, the instructional design using the modality principle was created using a document camera to record the researcher narrating the process of how to solve math problems in real time. To gain validity on the treatment form of instruction using the modality principle, a review panel of three people considered experts in the field of multimedia instruction provided feedback. The purpose of this review was to evaluate the instructional format for audio, clarity, lighting, and any other technologically related issues that may arise.

Because instruction designed under the modality principle guidelines could be distributed technologically via the Internet, the participants were able to access the instructional video via GoogleDocs. This allowed the panel to view the video and
provide feedback at their individual convenience, albeit by a given deadline. In essence, this process was similar to how nursing educators could provide math instruction to their students. Feedback was provided in both a Likert-scale survey and an open-ended short-answer format via GoogleDocs (see Appendix B). The feedback was used to improve the instruction designed using the modality principle.

**Expert review results.** After the experimental instructional design was completed, the video and feedback survey was distributed to three panelists considered expert in the field of multimedia design. Panelists were able to view and respond at their convenience, but by a given deadline. In a way, this was also a good way to test how adaptable the instruction is in a distance-learning environment because the material had been distributed via technology.

There were three consistent suggestions among the panelists. First, the lighting overall was good, but the shifting afternoon sunlight caused a glare in the top left-hand corner of the screen. Second, even though the pen was black ink, the writing needed to be darker and crisper. Thus, rather than using a pen, the visual aspect of the video was re-recorded using a thicker black marker. Lastly, the audio, though clear, sounded as though it was recorded in an empty chamber. This required an audio re-record with better placement of the speaker to the microphone.

After having received and reviewed the feedback, revisions were made to the instruction per the suggestions. Once the revisions were completed, a re-record of the instruction took place in preparation for the main study.
Procedures

There were 48 undergraduate participants enrolled in nursing programs from two northern California universities. These participants were randomly placed into one of two treatment groups: control (n = 22) and experimental (n = 26). Participants in the control group received visual-only instruction whereas participants in the experimental group received instruction using the modality principle.

There was a pre- and post-assessment in this study in addition to an instructional-design intervention. All participants regardless of treatment group completed pre- and post-assessments containing 15 algebraic math problems that ranged on three levels of complexity (low, moderate, and high). Levels of complexity and prior knowledge were previously determined by accuracy on a pre-assessment. Accuracy was scored 0 (incorrect) and 1 (correct). Cognitive load was also determined based on the perceived mental effort rating scale (Paas, 1992). Perceived mental effort was rated on a Likert-type scale ranging from 1 (very, very low mental effort) to 9 (very, very high mental effort).

The time to complete the study was a total of 53 consecutive minutes: 20 minutes for the pre-assessment, 13 minutes for the instructional intervention, and 20 minutes for the post-assessment. This time did not include the brief time it took to explain the overall process of the study to the participants and to obtain any remaining participant consent signatures.

Pre-Assessment. Both the control and experiment groups received the same pre-assessment. The pre-assessment included 15 mathematical problems separated into three categories: decimals, percentages, and fractions (Appendix C). This was meant to assess prior knowledge by way of accuracy and cognitive load by way of perceived mental
effort. This assessment was timed to last 20 minutes. Twenty minutes for the pre- and post-assessments was justified based on previous studies that use 20-minute timed sessions for assessments (Park, et al., 2010). The participants’ accuracy was based on the total number of correct responses. Participants assigned a definitive number to the level of perceived mental effort on a 9-point Likert scale where 1 = very, very low perceived mental effort and 9 = very, very high perceived mental effort (Paas, 1992, p. 430).

Whereas the pilot study was primarily meant to determine that there were at least three levels of complexity, the complexity levels based on the participant accuracy scores within the main study were used for analysis. There were three levels of complexity: low, moderate, and high, and the complexity levels were distributed throughout the assessment as to minimize a possible fatigue effect. A fatigue effect could occur if items incrementally become more difficult. By distributing the items, a more accurate assessment of performance was obtained. Items 1, 13, and 16 were omitted from the pilot study for the main study and, as indicated by Table 5, four items changed in complexity level from pilot to main. Specifically, items 7 and 13 changed from moderate to easy and items 11 and 14 changed from easy to moderate. Even though there was only a 6% difference in accuracy for item 7, it was a large enough difference to redistribute the complexity level.
Table 5

Levels of Complexity between Pilot and Pre-Assessment

<table>
<thead>
<tr>
<th>Item</th>
<th>Category</th>
<th>Pilot</th>
<th>Pre</th>
<th>Complexity Level Distribution Change?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Decimal</td>
<td>Moderate</td>
<td>Moderate</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>Decimal</td>
<td>Moderate</td>
<td>Moderate</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>Percentage</td>
<td>Low</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>Percentage</td>
<td>Low</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>Fraction</td>
<td>Low</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>Decimal</td>
<td>Low</td>
<td>Low</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>Decimal</td>
<td>Moderate</td>
<td>Low</td>
<td>Yes*</td>
</tr>
<tr>
<td>8</td>
<td>Percentage</td>
<td>Low</td>
<td>Low</td>
<td>No</td>
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<tr>
<td>9</td>
<td>Fraction</td>
<td>High</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td>10</td>
<td>Fraction</td>
<td>High</td>
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<td>No</td>
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<td>11</td>
<td>Fraction</td>
<td>Low</td>
<td>Moderate</td>
<td>Yes*</td>
</tr>
<tr>
<td>12</td>
<td>Percentage</td>
<td>High</td>
<td>High</td>
<td>No</td>
</tr>
<tr>
<td>13</td>
<td>Percentage</td>
<td>Moderate</td>
<td>Low</td>
<td>Yes*</td>
</tr>
<tr>
<td>14</td>
<td>Fraction</td>
<td>Low</td>
<td>Moderate</td>
<td>Yes*</td>
</tr>
<tr>
<td>15</td>
<td>Fraction</td>
<td>High</td>
<td>High</td>
<td>No</td>
</tr>
</tbody>
</table>

Note: * indicates change in complexity level from pilot of assessment to main study

**Post-Assessment.** Both the control and experiment groups received the same post-assessment. The post-assessment was similar to that of the pre-assessment such that the math problems were prompted the same way but with different numbers. Participants received 15 mathematical problems separated into three categories: decimals, percentages, and fractions (Appendix D) to complete within a 20-minute time limit just as the pre-assessment.

Access was granted to undergraduate students enrolled in two northern California universities from the respective schools of nursing. After receiving approval from USF IRBHS, the specific date and time to conduct the pilot and main studies was decided
upon with the professors who teach the aforementioned students. Participant consent was obtained prior to the pilot study and again before the main study.

Participation was considered a nonrandom selection because participants were enrolled in undergraduate nursing classes that were made available to conduct the pilot study and main study. The recruited participants for the pilot study completed the assessment as one group. Because participant consent was already gathered, the estimated time for the pilot study was 25 minutes – five minutes for a brief introduction and then a maximum time limit of 20 minutes to complete the assessment.

For the main study, participants were randomly selected to be part of either the control or the experiment group. This type of pre-separation is yet another example of nonrandom selection. The time to complete the main study was a consecutive 53 minutes. Because participant consent was already been gathered, five minutes was needed for a brief introduction and overview of the process. The remaining time was allotted for a 20-minute pre-assessment, 13-minute instructional intervention, and a 20-minute post-assessment. Twenty minutes for the pre- and post-assessments was justified based on previous studies that use 20-minute timed sessions for assessments (Park, et al., 2010). The intervention was 13 minutes because studies indicate that if instruction exceeds 20 minutes, essential processing is overloaded (McLeod, Fisher, & Hoover, 2003). Leahy and Sweller (2011) note that instruction using the modality principle has more benefit if the lesson has fewer visual images even with longer verbal explanation per image.
Treatment

Participants regardless of control or experimental grouping completed the pre-assessment in the allocated 20 minutes (Appendix C). The researcher distributed the pre-assessment packet upside-down to the participants. This process was to ensure that everyone would begin the packets at the start of the timer in order to ensure equal completion time. The pre-assessment included 15 mathematical problems that were categorized by fractions, decimals, and percentages. There was one problem per page. Participants were expected to solve each problem by hand per the directions presented at the top of each page. In addition to completing the math problems, participants completed a perceived mental effort rating survey after each math problem. Participants assigned a definitive number to the level of perceived mental effort on a 9-point Likert scale where 1 = very, very low perceived mental effort and 9 = very, very high perceived mental effort (Paas, 1992, p. 430).

Control. After the pre-assessment, each participant received visual-only instruction presented on paper that includes text and static images. An example of a math problem that is provided in visual-only format is presented in Figure 9.
Decimals

Equation: What is $x$ if $4.5 - 7.2 = 3.4x - 49.5$?

1. First, combine like terms
   $4.5 - 7.2 = -2.7$

2. Now the new equation looks like this
   $-2.7 = 3.4x - 49.5$

3. Combine like terms
   $49.5 + -2.7 = 3.4x$

4. Combine like terms again
   Because $2.7$ is a negative number, you can either
   $49.5 + -2.7$
   OR
   $49.5 - 2.7$.

5. The new equation looks like this
   $46.8 = 3.4x$

6. Get $x$ to stand by itself by dividing 3.4 from each side

$x = 13.76$

**Figure 9.** Example of a decimals math problem in visual-only format.

The visual-only instruction was created in accordance with Mayer’s (2009) spatial contiguity principle. Previous research on the spatial contiguity principle has indicated that text should be placed as close as possible to the corresponding image in order to avoid a split attention effect on working memory and to eliminate extraneous processing (Austin, 2009; Mayer, 2001). Participants were allowed 13 minutes to study the instruction. The text for the control was designed to act as the script for the narrated audio in the experimental form of instruction. The intention was to mimic the script from the control as best as possible for the audio. Moreover, the visual images designed for the control were also meant to act as the organizational outline for presenting the information in visual form.

**Experimental.** Participants received a 13-minute instruction using the modality principle. The instruction was provided as a movie. For this study, instruction was presented at once to the whole group using an LCD projector and
audio speakers. To make the instructional video, a document camera was used to record the researcher writing and solving worked out examples of algebraic math problems (Sweller, 1999) while narrating a self-explanation (Chi et al., 1994) of the process in real time. The audio mimicked the text version as closely as possible and the worked-out math problems mimicked those in the control group. The following four images demonstrate an example of a decimals problem worked out in chronological order. You will notice a hand acting as an arrow in images 2 and 3 guiding the viewers to follow the worked out example in sync with the narration.
After presenting the respective forms of instruction, all participants completed a post-assessment in the allocated 20 minutes just as for the pre-assessment (Appendix D). After each problem, participants self-reported their perceived level of mental effort.

**Data Analysis**

The two research questions that guided this study were intended to examine the results on a post-assessment after receiving one of two forms of instruction, visual-only or instruction designed using the modality principle with the prediction that the latter would confirm better outcomes. Those two guiding questions were:

1. Does instruction using the modality principle result in better accuracy as compared to visual-only instruction at each level of complexity as indicated by post-assessments?

2. Does instruction using the modality principle result in lower perceived mental effort when compared to visual-only instruction at each level of complexity as indicated by post-assessments?

Accuracy was scored as either 0 (incorrect) or 1 (correct). Then an average score was taken for each math problem to determine participant performance. Each average score for accuracy on the pre-assessment was then categorized into the three levels of complexity: low, moderate, and high. For instance, items 1, 2, 11, and 14 were placed in a moderate complexity group. Similarly, the average score for perceived mental effort on each item was calculated. Both research questions were answered through independent samples t-tests on the pre- and post-assessments. Cohen’s $d$ was calculated when statistically significant differences were found. The complexity level categories remained the same for the post-assessment, thus allowing the opportunity to analyze
change score results in a paired samples t-test.

Summary

The purpose of this study was to compare the effects of instructional design methods as math problems increased in complexity on perceived mental effort and accuracy for a group of undergraduate nursing students. A pilot study of the assessment instrument aided in determining the complexity levels of the math problems and the length of the study. An expert review panel was conducted to evaluate the instructional format using the modality principle. The study included a pre- and post-assessment in addition to a control or experimental format of instruction. A control group received visual-only instruction. An experiment group received instruction using the modality principle. Data analysis was conducted to determine the levels of complexity that instruction using the modality principle was most beneficial on accuracy and perceived mental effort.
CHAPTER IV

RESULTS

The purpose of this study was to compare the effects of two instructional formats on math accuracy and perceived mental effort as indicated by a post-assessment. Participants included 48 undergraduate nursing students spanning two northern California universities who completed a series of math problems across three levels of complexity: low, moderate, and high. The independent variable was based on two levels: experimental instruction and control instruction. One group (n = 26) of participants received an experimental form of instruction using the guidelines of the modality principle (Mayer, 2009), and one group (n = 22) received a traditional form of instruction using visual-only materials (Costello, 2010). The dependent variables were accuracy and perceived mental effort. Measuring perceived mental effort in addition to accuracy provided a stronger indicator of cognitive load because not only is performance assessed but also the mechanics of the cognitive load processes (Paas & van Merrienboër, 1994). In addition to the original intention of analyzing performance and mental effort, it had become of interest to collect ancillary data on confidence on math performance before and after receiving a respective form of instruction (Halford, Baker, McCredden, & Bain, 2005; Moreno, 2005). More on confidence and the justification for this data collection will be discussed later in this chapter.

It was hypothesized that as the math problems increased in complexity, both accuracy and perceived mental effort would be negatively impacted. However, it was predicted that the participants who received instruction using the modality principle
would have better accuracy and lower perceived mental effort than the control group.

The research questions that guided this study were:

1. Does instruction using the modality principle result in better accuracy as compared to visual-only instruction at each level of complexity as indicated by post-assessments?

2. Does instruction using the modality principle result in lower perceived mental effort when compared to visual-only instruction at each level of complexity as indicated by post-assessments?

**Establishing Prior Knowledge and Complexity Levels**

All participants completed the same pre-assessment regardless of assignment to the control or treatment group to gain baseline information on prior knowledge and item complexity level. The first piece of information needed was to establish a sense of participant prior knowledge. Getting a better sense of prior knowledge gave way to analyzing the improved levels of knowledge after receiving instruction. As represented in Table 6, we can see that there were low levels of prior knowledge for items 9, 10, and 15 because less than 70% of participants were able to answer those problems correctly. There was a moderate level (71-79%) of prior knowledge for items 1, 2, 4, 5, 11, 12, and 14. Lastly, there was an indication of high prior knowledge on items 3, 6, 7, 8, and 13 because more than 80% of participants were able to answer those problems correctly.
### Table 6

**Pre-assessment Descriptive Statistics on Accuracy** (n = 48)

<table>
<thead>
<tr>
<th>Items</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.75</td>
<td>0.75</td>
<td>0.88</td>
<td>0.79</td>
<td>0.79</td>
<td>0.85</td>
<td>0.83</td>
<td>0.9</td>
<td>0.27</td>
<td>0.5</td>
<td>0.73</td>
<td>0.69</td>
<td>0.83</td>
<td>0.71</td>
<td>0.50</td>
</tr>
<tr>
<td>SD</td>
<td>0.44</td>
<td>0.44</td>
<td>0.33</td>
<td>0.41</td>
<td>0.41</td>
<td>0.36</td>
<td>0.31</td>
<td>0.45</td>
<td>0.51</td>
<td>0.45</td>
<td>0.47</td>
<td>0.38</td>
<td>0.46</td>
<td>0.51</td>
<td></td>
</tr>
</tbody>
</table>
While the pilot test was meant to determine that there were at least three levels of complexity across the items, the pre-assessment in the main study established the complexity level for each item. There were three levels of complexity confirmed based on the pre-assessment: low, moderate, and high. Complexity was discerned by participant accuracy. Using Brown’s (2006) guidelines that 70% and above is passing, it was noted that items that were answered incorrectly at least 69% of the time or less were considered high in complexity, items that were accurate 71-79% were considered moderate in complexity, and items that were accurate 80-100% were considered low in complexity.

Table 7 presents items, categories, and level of complexity as determined by the pre-assessment. Items of low complexity involved problems with decimals and percentages only. Items of moderate complexity involved problems with fractions, decimals, combinations of decimals and fractions, and combinations of percentages and fractions. Items of high complexity included percentages, combinations of decimals and percentages, and combinations of decimals and fractions.

After conducting descriptive statistics on each item within the pre-assessment, items were then categorized within a specific level of complexity. As depicted in Table 7, items 3, 6, 7, 8, and 13 were considered low complexity. Items 1, 2, 4, 5, 11, 12, and 14 were moderate in complexity. It had been advised to include item 12 (M = 0.69) in the moderate complexity level because it was on the cusp between high and moderate levels. Items 9, 10, and 15 were considered high in complexity.
Table 7

<table>
<thead>
<tr>
<th>Item</th>
<th>Category</th>
<th>Complexity Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Decimal</td>
<td>Moderate</td>
</tr>
<tr>
<td>2</td>
<td>Decimal</td>
<td>Moderate</td>
</tr>
<tr>
<td>3</td>
<td>Decimal</td>
<td>Low</td>
</tr>
<tr>
<td>4</td>
<td>Decimal</td>
<td>Moderate</td>
</tr>
<tr>
<td>5</td>
<td>Decimal</td>
<td>Moderate</td>
</tr>
<tr>
<td>6</td>
<td>Percent</td>
<td>Low</td>
</tr>
<tr>
<td>7</td>
<td>Percent</td>
<td>Low</td>
</tr>
<tr>
<td>8</td>
<td>Percent</td>
<td>Low</td>
</tr>
<tr>
<td>9</td>
<td>Decimal/Percent</td>
<td>High</td>
</tr>
<tr>
<td>10</td>
<td>Percent</td>
<td>High</td>
</tr>
<tr>
<td>11</td>
<td>Fraction/Decimal</td>
<td>Moderate</td>
</tr>
<tr>
<td>12</td>
<td>Percent/Fraction</td>
<td>Moderate</td>
</tr>
<tr>
<td>13</td>
<td>Decimal</td>
<td>Low</td>
</tr>
<tr>
<td>14</td>
<td>Fraction</td>
<td>Moderate</td>
</tr>
<tr>
<td>15</td>
<td>Decimal/Fraction</td>
<td>High</td>
</tr>
</tbody>
</table>

Research Question 1

The first research question asked if instruction using the modality principle resulted in better accuracy as compared to visual-only instruction at each level of complexity as indicated by post-assessments. The hypothesis was that while accuracy would decrease (as complexity increased) in both treatment groups regardless of instruction, the experimental group receiving instruction using the modality principle would have better accuracy than the control group receiving visual-only instruction.

Prior to looking at differences on post-assessments across treatment groups, students’ prior knowledge on the pre-assessment were examined. Pre-assessment descriptive statistics on accuracy for each treatment group at each level of complexity are presented in Table 8. For scores that yielded statistically significant differences, Cohen’s d effect sizes were calculated. For the pre-test, independent t-test results indicate that
both treatment groups had similar prior knowledge for items of low and high complexity; unexplainably, the experimental group scored higher on items of moderate complexity ($t(47)= 1.89, p = .07, d = .54$).

<table>
<thead>
<tr>
<th>Complexity Level</th>
<th>Treatment</th>
<th>$t$</th>
<th>$df$</th>
<th>Sig. (2-tailed)</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Control (n = 22)</td>
<td>0.83 (0.23)</td>
<td></td>
<td>0.79</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>Experimental (n = 26)</td>
<td>0.88 (0.21)</td>
<td></td>
<td>0.00</td>
<td>47</td>
</tr>
<tr>
<td>Moderate</td>
<td>Control (n = 22)</td>
<td>0.66 (0.33)</td>
<td></td>
<td>1.89</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>Experimental (n = 26)</td>
<td>0.82 (0.26)</td>
<td></td>
<td>0.00</td>
<td>47</td>
</tr>
<tr>
<td>High</td>
<td>Control (n = 22)</td>
<td>0.42 (0.40)</td>
<td></td>
<td>0.00</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>Experimental (n = 26)</td>
<td>0.42 (0.33)</td>
<td></td>
<td>0.00</td>
<td>47</td>
</tr>
</tbody>
</table>

To answer the first research question, Table 9 presents the independent samples t-test that was conducted on the post-assessment accuracy scores at each level of complexity and by treatment group. For scores that yielded statistically significant differences, Cohen’s $d$ effect sizes were calculated. Post-test results suggest a significant difference on items of moderate complexity ($t(47)= 3.97, p < .00, d = 1.20$). Though not significant, accuracy was also better for the experimental group on items of low complexity with a moderate effect size ($t (47)= 1.94, p = 0.06, d = 0.60$).
In addition to answering the first research question, it also became of interest to analyze the difference from pre- to post-assessment scores within a group in order to better understand the level of significance in score changes. To do so, a paired samples t-test was conducted to analyze the difference on accuracy at each level of complexity from pre to post-assessment for the control and experimental treatments (Tables 10 and 11 respectively). There were no significant changes from pre to post assessment within either the control or experimental groups as indicated in Tables 10, and 11 respectively.
Table 10

_Paired Samples t-test for Accuracy between Pre and Post Assessments at Each Level of Complexity and Overall Regardless of Treatment_

<table>
<thead>
<tr>
<th>Complexity Level</th>
<th>M</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>0.06</td>
<td>0.27</td>
<td>1.48</td>
<td>47</td>
<td>0.15</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.01</td>
<td>0.35</td>
<td>0.30</td>
<td>47</td>
<td>0.77</td>
</tr>
<tr>
<td>High</td>
<td>-0.13</td>
<td>0.54</td>
<td>-1.71</td>
<td>47</td>
<td>0.95</td>
</tr>
<tr>
<td>Overall</td>
<td>0.00</td>
<td>0.29</td>
<td>0.00</td>
<td>47</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table 11

_Paired Samples t-test for Accuracy between Pre and Post Assessments at Each Level of Complexity for the Control Group_

<table>
<thead>
<tr>
<th>Complexity Level</th>
<th>Treatment</th>
<th>M (SD)</th>
<th>M (SD)</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Pre-test</td>
<td>0.83 (0.23)</td>
<td>0.73 (0.28)</td>
<td>1.33</td>
<td>21</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>Post-test</td>
<td>0.66 (0.33)</td>
<td>0.58 (0.30)</td>
<td>0.77</td>
<td>21</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.42 (0.40)</td>
<td>0.58 (0.37)</td>
<td>-1.31</td>
<td>21</td>
<td>0.20</td>
<td>0.20</td>
</tr>
</tbody>
</table>
Table 12

*Paired Samples t-test for Accuracy between Pre and Post Assessments at Each Level of Complexity for the Experimental Group*

<table>
<thead>
<tr>
<th>Complexity Level</th>
<th>Treatment</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test (n=26)</td>
<td>M (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post-test (n = 26)</td>
<td>M (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>0.88 (0.21)</td>
<td>0.86 (0.18)</td>
<td>0.65</td>
<td>25</td>
<td>0.52</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.82 (0.26)</td>
<td>0.85 (0.16)</td>
<td>-0.66</td>
<td>25</td>
<td>0.51</td>
</tr>
<tr>
<td>High</td>
<td>0.42 (0.33)</td>
<td>0.54 (0.39)</td>
<td>-1.09</td>
<td>25</td>
<td>0.29</td>
</tr>
</tbody>
</table>

In sum, results are in line with Schnotz’s (2011) argument that a modality effect does not occur under all conditions as further demonstrated in Table 12. Accuracy differences occurred at levels other than high, unlike Moreno’s (2006) conclusion, perhaps because of gender and learning style preferences. While not a significant change, accuracy decreased for the control group possibly because of Sweller’s (1988) split-attention effect.

Moreno (2006) also suggested that modality principle holds strongest for tasks where learners are not able to control the pace of the presentation of instructional materials. Even though each treatment group received the same amount of instruction time, the experimental group was not able to self-pace the instruction whereas the control group had the implicit opportunity to re-read and review the information as many times as allowed within the allotted time.

Furthermore, Paas et al. (2003) had postulated that a modality effect may not occur for tasks of low complexity. The thought was that a modality effect occurs when more information needs to be cognitively processed because it is those times of higher
levels of cognitive demand when the limited resources within the visual channel of working memory should be freed to decrease potential cognitive overload. This present study suggests that significant differences occur at levels of lower cognitive demands.

**Research Question 2**

The second research question asked if instruction using the modality principle resulted in lower perceived mental effort when compared to visual-only instruction at each level of complexity as indicated by post-assessments. Perceived mental effort was rated after each item on a Likert-type scale ranging from 1 (very, very low mental effort) to 9 (very, very high mental effort) as designed by Paas (1992). The hypothesis was that while perceived mental effort would increase in both treatment groups regardless of instruction, the experimental group receiving instruction using the modality principle would still have lower perceived mental effort than the control group receiving visual-only instruction.

Pre-assessment descriptive statistics on perceived mental effort for each treatment group at each level of complexity are presented in Table 13. For scores that yielded significant levels, Cohen’s d effect sizes were calculated. Both treatment groups scored similarly on items of moderate levels of complexity. There was a significant difference for items of high complexity with a strong effect size ($t(47) = 3.64, p = 0.00, d = 1.05$). It is unclear as to why there is a significant difference at the high level of complexity given that one would expect similar levels of perceived mental effort at the pre-assessment prior to any form of instructional treatment.
Table 13

*Independent Samples t-test for Pre-Assessment Perceived Mental Effort Scores for each Treatment Group at Each Level of Complexity*

<table>
<thead>
<tr>
<th>Complexity Level</th>
<th>Treatment</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Experimental</td>
<td>1.96</td>
<td>47</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>(n = 22)</td>
<td>(n = 26)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>3.02 (1.11)</td>
<td>3.79 (1.53)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>3.29 (1.49)</td>
<td>4.00 (1.70)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>3.79 (1.85)</td>
<td>6.03 (2.33)</td>
<td></td>
<td></td>
<td>0.00*</td>
</tr>
</tbody>
</table>

To answer the second research question, Table 14 presents the independent samples t-tests that were conducted for post-assessment perceived mental effort scores at each level of complexity and by treatment group. Perceived mental effort was not lower for the experimental group as hypothesized across the various levels of complexity.

Table 14

*Independent Samples t-test on Post-Assessment Mental Effort Between Treatment Groups for Each Level of Complexity*

<table>
<thead>
<tr>
<th>Complexity Level</th>
<th>Treatment</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Experimental</td>
<td>1.36</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>(n = 22)</td>
<td>(n = 26)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>2.85 (1.22)</td>
<td>3.45 (1.73)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>3.52 (1.15)</td>
<td>3.41 (1.56)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>3.89 (2.07)</td>
<td>4.84 (2.53)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Compared to the pre-assessment data, however, it should be noted that perceived mental effort decreased at each level of complexity for the experimental group whereas
perceived mental effort increased on items of moderate and high complexity for the control group. Thus, similar to further analyzing the first research question, it also became of interest to analyze the difference of perceived mental effort ratings from pre- to post-assessment scores within a group in order to better understand the level of significance in score changes. Again, paired samples t-tests were conducted to analyze the difference overall and at each level of complexity from pre to post-assessment in accordance to treatment (Table 15 for control and Table 16 for experimental). We can see that there were no statistically significant differences in pre- and post-assessment scores in Table 15 for the control group.

![Table 15](image)

Table 15

*Paired Samples t-test for Perceived Mental Effort between Pre and Post Assessments at Each Level of Complexity for the Control Group*

<table>
<thead>
<tr>
<th>Complexity Level</th>
<th>Treatment</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>(n=26)</td>
<td>(n = 26)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.02 (1.11)</td>
<td>2.85 (1.22)</td>
<td>0.50</td>
<td>21</td>
<td>0.62</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.29 (1.49)</td>
<td>3.52 (1.15)</td>
<td>-0.06</td>
<td>21</td>
<td>0.56</td>
</tr>
<tr>
<td>High</td>
<td>3.79 (1.85)</td>
<td>3.89 (2.07)</td>
<td>-0.17</td>
<td>21</td>
<td>0.86</td>
</tr>
</tbody>
</table>

However, there were noticeable statistical differences for the experimental group as depicted in Table 16. Perceived mental effort significantly decreased for the experimental group on items of high complexity with a strong effect size ($t(25) = 2.55$, $p = 0.02$, $d = 0.60$). This result was expected based on previous work done by Paas and van Merrienböer (1992, 1994).
Table 16

*Paired Samples t-test for Perceived Mental Effort between Pre and Post Assessments at Each Level of Complexity for the Experimental Group*

<table>
<thead>
<tr>
<th>Complexity Level</th>
<th>Treatment</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-test</td>
<td>(n=26)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-test</td>
<td>(n = 26)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>3.79 (1.53)</td>
<td>3.45 (1.73)</td>
<td>1.12</td>
<td>25</td>
<td>0.28</td>
</tr>
<tr>
<td>Moderate</td>
<td>4.00 (1.70)</td>
<td>3.41 (1.56)</td>
<td>1.78</td>
<td>25</td>
<td>0.09</td>
</tr>
<tr>
<td>High</td>
<td>6.03 (2.33)</td>
<td>4.84 (2.53)</td>
<td>2.55</td>
<td>25</td>
<td>0.02* 0.60</td>
</tr>
</tbody>
</table>

We can see in Figure 10 that though the experimental group initially rated its perceived mental effort much higher than the control group on the pre-assessment for no explainable reason, the group largely decreased its ratings on items of high complexity. Coincidentally, the control group increased its ratings, albeit not significantly.

*Figure 10.* Perceived Mental Effort rating difference from pre- to post assessment at the high level of complexity.
Ancillary Analysis

According to the National Council of Teachers of Mathematics Standards for School Mathematics, students tend to develop confidence in instructionally supportive learning environments that allow them to explore problems and adjust strategies. Even though not initially intended to be analyzed in this current study, ancillary data was collected on confidence (Halford, Baker, McCredden, & Bain, 2005). Confidence became of interest to assess because this current study was inspired in part by Halford et al., who also measured confidence in conjunction to accuracy as part of their study. Halford and his colleagues reported that confidence decreased as complexity levels increased.

This study examined the impact of confidence in multimedia learning by asking if confidence moderates the modality effect. The Cognitive Affective Theory of Learning with Media (CATLM; Moreno, 2005) suggests that affective factors such as confidence influence the amount of cognitive resources used (Moreno, 2006) and act as intermediaries to learning by changing the demands placed on cognitive engagement (Pintrich, 2003). Prior knowledge may also affect outcomes during multimedia instruction (Moreno, 2004; Moreno & Mayer, 2007; Moreno & Duran, 2004; Schnotz, 2011). Affective constructs have influenced learning when applied to the modality principle (Moreno, 2006). Mayer’s (2001; 2009) MP postulates that deeper learning occurs when information is presented simultaneously through audio-visual formats as compared to visual-only material because fewer cognitive resources are needed. Despite previously reported positive outcomes, Schnotz (2011) argues that a modality effect does not occur under all conditions. Thus, through a pre-post-test quasi-experimental design in
the present study, the relationship between confidence and accuracy prior to, as well as after, the intervention were accounted for.

Because there is little research on confidence, it was not clear how confidence would be impacted. Thus, in addition to accuracy and mental effort, the affective construct of confidence was measured. Thus, this current study asked if confidence moderates the modality principle, and if the modality principle moderates confidence after instruction. The relationship between confidence and learning outcomes prior to, as well as after the intervention were accounted for, allowing for additional analysis. It was hypothesized in this current study that confidence would, too, decrease as complexity increased; however, it was thought that confidence would not decrease as much in the experimental group that received instruction with the modality principle as the control group that received visual-only instruction.

Participants were asked to rate their perceived level of confidence in solving each of the math items correctly. Confidence was rated after each item on a Likert-type scale ranging from 1 (very low confidence) to 5 (very high confidence) as used in the Halford et al. (2005) study (Appendix C and Appendix D).

Pre-assessment descriptive statistics on confidence for each treatment group at each level of complexity are presented in Table 17. We see that even though the results appear to look similar between groups, the experimental group rated higher confidence at statistically significant levels than the control group on items of moderate complexity with a strong effect size ($t (47) = 3.28, p = 0.00, d = 0.95$) and on items of high complexity with a strong effect size ($t (47) = 2.76, p = 0.01, d = 0.80$). There is no
explainable reason for this because participants had been as equally distributed between both treatment groups as possible.

Table 1

<table>
<thead>
<tr>
<th>Complexity Level</th>
<th>Treatment</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Control (n = 22)</td>
<td>3.83 (0.76)</td>
<td>1.01</td>
<td>47</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>Experimental (n = 26)</td>
<td>4.08 (0.93)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>Control (n = 22)</td>
<td>3.14 (0.78)</td>
<td>3.28</td>
<td>47</td>
<td>0.00*</td>
</tr>
<tr>
<td></td>
<td>Experimental (n = 26)</td>
<td>3.88 (0.78)</td>
<td></td>
<td></td>
<td>0.95</td>
</tr>
<tr>
<td>High</td>
<td>Control (n = 22)</td>
<td>2.06 (1.26)</td>
<td>2.76</td>
<td>47</td>
<td>0.01*</td>
</tr>
<tr>
<td></td>
<td>Experimental (n = 26)</td>
<td>3.04 (1.20)</td>
<td></td>
<td></td>
<td>0.80</td>
</tr>
</tbody>
</table>

An independent samples t-test was conducted on the post-assessment results for each treatment group at each level of complexity. As indicated by the results in Table 18, the experimental group rated lower confidence on the post-assessment compared to the control group, though not at statistically significant levels. Based on the information from the pre-assessment, confidence decreased for the experimental group at each level of complexity whereas the control group rated higher confidence on each level of complexity after instruction.
Same as with the two guiding research questions, it was also of interest to analyze the difference in confidence ratings from pre- to post-assessment scores within a group in order to better understand the level of significance in score changes. To do so, a paired samples t-test was conducted to analyze the difference overall and at each level of complexity from pre to post-assessment.

Unexpectedly, there were significant changes, albeit with small effect sizes, for the control group as presented in Table 19. This group increased its confidence ratings after receiving the visual-only instruction specifically on items of moderate ($t(21) = -3.90$, $p < 0.00$, $d = 0.30$) and high ($t(21) = -3.59$, $p < 0.00$, $d = 0.10$) levels of complexity in addition to overall significant increases ($t(21) = -3.31$, $p < 0.00$, $d = 0.23$).

### Table 18

<table>
<thead>
<tr>
<th>Complexity Level</th>
<th>Treatment</th>
<th>$t$</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control (n = 22)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Experimental (n = 26)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.05 (0.77)</td>
<td>3.87 (0.97)</td>
<td>0.70</td>
<td>47</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.97 (0.60)</td>
<td>3.59 (1.02)</td>
<td>1.51</td>
<td>47</td>
</tr>
<tr>
<td>High</td>
<td>3.17 (0.80)</td>
<td>2.87 (1.31)</td>
<td>0.94</td>
<td>47</td>
</tr>
</tbody>
</table>
Table 19

*Paired Samples t-test for Confidence between Pre and Post Assessments at Each Level of Complexity for the Control Group*

<table>
<thead>
<tr>
<th>Complexity Level</th>
<th>Treatment</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(n=26)</td>
<td>(n = 26)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>3.83 (0.76)</td>
<td>4.05 (0.77)</td>
<td>-1.07</td>
<td>21</td>
<td>0.30</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.14 (0.78)</td>
<td>3.97 (0.60)</td>
<td>-3.90</td>
<td>21</td>
<td>0.00*</td>
</tr>
<tr>
<td>High</td>
<td>2.06 (1.26)</td>
<td>3.17 (0.80)</td>
<td>-3.59</td>
<td>21</td>
<td>0.00*</td>
</tr>
</tbody>
</table>

Just as unexpectedly, the experimental group did not demonstrate any significant changes in its confidence ratings and more so, this group decreased its confidence ratings after receiving instruction using the modality principle as reported in Table 20.

Table 20

*Paired Samples t-test for Confidence between Pre and Post Assessments at Each Level of Complexity for the Experimental Group*

<table>
<thead>
<tr>
<th>Complexity Level</th>
<th>Treatment</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Cohen's d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(n=26)</td>
<td>(n = 26)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>4.08 (0.93)</td>
<td>3.87 (0.97)</td>
<td>0.97</td>
<td>25</td>
<td>0.34</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.88 (0.78)</td>
<td>3.59 (1.02)</td>
<td>1.26</td>
<td>25</td>
<td>0.22</td>
</tr>
<tr>
<td>High</td>
<td>3.04 (1.20)</td>
<td>2.87 (1.31)</td>
<td>0.50</td>
<td>25</td>
<td>0.63</td>
</tr>
</tbody>
</table>

The control group rated an increased level of confidence from pre- to post-assessment at each level of complexity, specifically at significant levels at the moderate and high levels of complexity. The control group not only rated higher confidence from pre- to post-assessment, but the experimental group decreased its ratings of confidence.
from pre- to post-assessment. It is of interest to continue exploring these data and results because the original hypothesis that the experimental group would demonstrate higher confidence than the control group was rejected.

These results suggest that significant differences occur at levels of lower cognitive demands unlike Paas et al. (2003) had postulated that a modality effect may not occur for tasks of low complexity with the notion that a modality effect occurs when more information needs to be cognitively processed; it is those times of higher levels of cognitive demand when the limited resources within the visual channel of working memory should be freed to decrease potential cognitive overload. Moreover, the results do not confirm the study conducted by Halford et al. (2005) in which confidence was shown to decrease as complexity increased with visual-only instruction. In fact, the control group rated an increased level of confidence from pre- to post-assessment at each level of complexity, specifically at significant levels at the moderate and high levels of complexity. The control group not only rated higher confidence from pre- to post-assessment, but the experimental group decreased its ratings of confidence from pre- to post-assessment. It is of interest to continue exploring these data and results because the original hypothesis that the experimental group would demonstrate higher confidence than the control group was rejected.

**Relationship between Accuracy, Perceived Mental Effort, and Confidence**

Because of the decrease in confidence for the experimental group and the increase in confidence for the control group from pre- to post-assessments, it was of further interest to examine the correlations between confidence and accuracy, in addition to confidence and perceived mental effort, on the post-assessment. Table 21 presents
correlations between confidence and accuracy, and perceived mental effort, for both
treatment groups at each level of complexity. A correlation for the control group
between confidence and accuracy on items of low complexity was significant \( r(20) = 0.42, p = 0.05 \) and, there was a statistically significant correlation for the control group
between confidence and accuracy on items of high complexity \( r(20) = 0.53, p = 0.01 \).
Additionally, there was a statistically significant negative correlation for the control
group between confidence and perceived mental effort on items of low complexity \( r(20) = -0.50, p = 0.02 \). A possible implication of this result could indicate that on items of
low complexity, cognitive load decreases and confidence increases. The experimental
group demonstrated a statistically significant negative correlation between confidence
and perceived mental effort for items of low complexity \( r(24) = -0.40, p = 0.04 \).
Interestingly in this case, perceived mental effort decreased as confidence decreased.

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Level of Complexity</th>
<th>Accuracy &amp; Confidence</th>
<th>Perceived Mental Effort &amp; Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (n = 22)</td>
<td>Low</td>
<td>0.42 (20) 0.05*</td>
<td>-0.50 (24) 0.02*</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>0.31 (20) 0.20</td>
<td>-0.30 (24) 0.24</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.53 (20) 0.01*</td>
<td>-0.04 (24) 0.85</td>
</tr>
<tr>
<td>Experimental (n = 26)</td>
<td>Low</td>
<td>0.05 (24) 0.81</td>
<td>-0.40 (24) 0.04*</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td>0.35 (24) 0.08</td>
<td>-0.38 (24) 0.06</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>0.21 (24) 0.30</td>
<td>-0.17 (24) 0.40</td>
</tr>
</tbody>
</table>
Moreno (2006) reported that learners who received a narrated instructional video outperformed those who learned with text only (p < 0.001). Where Moreno’s results further support the notion that the modality principle as part of CATLM is an effective multimedia instructional method, this present study suggests otherwise. These results show an interaction between confidence and instruction.; however, these results do not support Moreno’s (2006) conclusion that the modality principle holds strongest for tasks that require higher cognitive demands and where learners are not able to control the pace of the presentation of instructional materials. Even though both treatment groups received the same amount of instruction time, the experimental group was not able to self-pace the instruction whereas the control group had the implicit opportunity to re-read and review the information as often as allowed within the allotted time.

An additional correlation was run between accuracy and perceived mental effort. As an extension to the DeLeeuw and Mayer (2008) study, it was hypothesized in this current study that perceived mental effort ratings would increase as complexity increases and perceived mental effort ratings would be low on math problems that are low in complexity. It was unclear if perceived mental effort can plateau at a given level of complexity. Perceived mental effort ratings, referred to as difficulty ratings within that specific study, were assessed by participants’ level of performance on a final assessment after receiving a treatment. The level of effort was most connected with generative processing.

DeLeeuw and Mayer (2008) considered three options between accuracy and perceived mental effort. First, participants who scored low on the performance
assessment should have rated their perceived mental effort higher. Second, participants who scored high on the assessment should have rated lower on their perceived mental effort rating. Third, a high perceived mental effort rating could indicate more generative processing that could lead to high performance. DeLeeuw and Mayer reported no significant correlations between accuracy and perceived mental effort.

The results in this current study suggest that there were statistically significant negative correlations on the post-assessment for the experimental group at levels of moderate and high complexity ($r (24) = -0.44, p = 0.02$). This was the only statistically significant correlation found between accuracy and perceived mental effort for both the control and experimental groups at each level of complexity. These negative correlations indicate the second option presented by DeLeeuw and Mayer such that accuracy was high with ratings of low perceived mental effort.

**Summary**

Forty-eight 2nd-year university nursing students spanning two northern California universities (22 control; 40 female) completed 15 math problems consisting of algebra concepts involving mixed numbers and three levels of complexity: low, moderate, and high. The control instruction consisted of learning material presented in a visual-only format whereas the experimental instruction used the guidelines of the modality principle by converting the text into audio and the printed worked-out examples into real-time dynamic images. Prior knowledge was measured by a pre-assessment and learning outcomes were measured by using this same pre-assessment as the post-assessment immediately after the instruction. Cognitive engagement was measured through a widely used participant-rated mental effort scale after each math problem (Paas, 1992). On the
pre- and post-assessments, participants rated self-perceived levels of confidence after completing each math problem (Halford et al., 2005). Data were analyzed by treatment group and at each level of complexity.

Independent samples t-tests were conducted to analyze the data on accuracy, perceived mental effort, and confidence. Additional paired samples t-tests were conducted to further examine the difference in change scores for accuracy, perceived mental effort, and confidence at each level of complexity from pre- to post-assessment. The results suggest that the experimental group that received instruction using the modality principle had better accuracy on the post-assessment than the control group on items of moderate complexity, though none of the results demonstrate a modality effect on such learning outcomes.

With regard to perceived mental effort on the post-assessment, independent t-tests showed that the experimental group rated higher perceived mental effort at each level of complexity than the control group, though not at statistically significant levels. However, after analyzing the paired sample t-tests from pre- to post-assessments, the experimental group significantly decreased its mental effort ratings on items of high complexity with a strong effect size.

After collecting and analyzing ancillary data on confidence ratings, data indicated a correlation on the post-assessment to answer if confidence moderates the modality effect. A significant correlation occurred for the control group between confidence and accuracy on items of low and high complexity, though no significant modality effect occurred at any level of complexity. A significant negative correlation for the control group between confidence and perceived mental effort on items of low complexity
indicating that on items of low complexity, cognitive load decreases and confidence increases. The experimental group demonstrated a significant negative correlation between confidence and perceived mental effort for items of low complexity suggesting that confidence decreased as perceived mental effort decreased.

Paired-sample t-tests were conducted to answer if the modality principle moderates the confidence. Confidence significantly increased for the control group despite decreased learning outcomes. Unexpected and significant changes, albeit with small effect sizes, occurred specifically on items of moderate and high complexity additionally to overall significant increases. On the contrary, the experimental group decreased in levels of confidence, though not significantly, even though learning outcomes improved.

These findings, whether confirming or disputing prior reports, open a great deal of reasoning as to why these results may have occurred. Discussion with respect to an overconfidence effect, influence of prior knowledge, gender stereotype threat and gender itself, self-efficacy, and learning style preferences will take place within Chapter 5.
CHAPTER V

DISCUSSION

This chapter presents a summary of the study in addition to a presentation of research findings, potential limitations, research contributions, practical educational implications, directions for future research, and conclusions. The findings presented in Chapter 4, whether confirming or disputing prior reports, open a great deal of reasoning as to why these results may have occurred. An integrated discussion will also take place with respect to gender in addition to learning style preferences, influence of prior knowledge, an overconfidence effect, and self-esteem throughout this chapter.

Summary of Study

Forty-eight 2nd-year university nursing students spanning two northern California universities (22 control; 40 female) completed 15 math problems consisting of algebra concepts involving mixed numbers and three levels of complexity: low, moderate, and high. The control instruction consisted of learning material presented in a visual-only format whereas the experimental instruction used the guidelines of the modality principle by converting the text into audio and the printed worked-out examples into real-time dynamic images. Prior knowledge was measured by a pre-assessment and learning outcomes were measured by using this same pre-assessment as the post-assessment immediately after the respective instruction. Cognitive load was measured through a widely used participant-rated mental effort scale after each math problem (Paas, 1992). On the pre- and post-assessments, participants rated self-perceived levels of confidence after completing each math problem (Halford et al., 2005).
This study was in part influenced by first, the lack of explicit math instruction in undergraduate nursing courses despite its inclusion on exit exams and use of within the field and second, nursing students demonstrate low performance rates on math problems that involve fractions, decimals, and percentages (Brown, 2006). In this study, the possibility of adapting a multimedia format using the modality principle as a way to conveniently and explicitly introduce math instruction into an already rigorous course load was explored. If there is any form or amount of math instruction within nursing, very few studies, and much less current research, examine the impact of instructional design on learning outcomes.

Math problems that include mixed numbers also tend to range in complexity levels. One explanation for low performance on those specific math problems is cognitive load, which is very much connected to instructional design. Providing explicit math instruction through the modality principle was found to improve accuracy. Measuring perceived mental effort in addition to accuracy provided a stronger indicator of cognitive load not only because performance was assessed but also the mechanics of the cognitive load processes was studied (Moreno, 2005; Paas & van Merrienboër, 1994). Understanding the cognitive load processes acts as a conduit to properly designing instruction specifically with the modality principle.

Mayer’s cognitive theory of multimedia learning (CTML; 2001) provided the theoretical framework for this study. CTML effectively combines the use of technology through multimedia instruction and the cognitive learning processes, and it may help instructors overcome the constraints of rigorous in-class course loads by appropriately integrating technology into a learning environment. Thus far, research on the modality
principle has reported positive effects on accuracy (Mayer, 2009) and perceived mental effort (Sweller, van Merrienboer, & Paas, 1998; Tabbers, Martens, & van Merrienboer, 2001; Tindall-Ford, et al., 1997). Research also indicates that tasks of high complexity have negative effects on accuracy and perceived mental effort such as multi-step algebraic math problems (Halford, et al., 2005).

This study also examined the impact of confidence and multimedia instruction on learning outcomes. Cognitive Affective Theory of Learning with Media (CATLM; Moreno, 2005) suggests that affective factors such as confidence not only influence the amount of cognitive resources used (Moreno, 2006), but they also act as intermediaries to learning outcomes. Moreover, affective constructs influence learning when applied to variations of the modality principle (Moreno, 2006); hence, the impact of confidence on accuracy when learning with the modality principle and variations of that concept was explored by asking if confidence moderated the modality principle. The relationship between confidence and learning outcomes prior to, as well as after the intervention were accounted for, allowing for additional analysis.

The multimedia instruction results were compared against a traditional form of instruction using visual-only teaching materials. Results on accuracy, perceived mental effort, and confidence were analyzed using independent t-tests between the two instructional groups based on three levels of complexity in addition to paired sample t-tests to examine the difference in scores from pre- to post-assessment.

**Discussion of Findings**

This section will briefly reiterate the results previously presented in Chapter 4 and then expand on those findings. The first discussion refers to accuracy, the second to
mental effort, and the final presents confidence. To recap, the two primary research questions that guided this study were:

1. Does instruction using the modality principle result in better accuracy as compared to visual-only instruction at each level of complexity as indicated by post-assessments?

2. Does instruction using the modality principle result in lower perceived mental effort when compared to visual-only instruction at each level of complexity as indicated by post-assessments?

**Research Question 1**

The first research question asked if instruction using the modality principle resulted in better accuracy as compared to visual-only instruction at each level of complexity as indicated by post-assessments. A pre-assessment was administered to better establish a baseline of prior knowledge. Based on the independent t-test for each treatment group on the pre-assessment, both groups were extremely similar in accuracy scores for items of low and high complexity; however, there was nearly a significant difference in scores for items of moderate complexity where the experimental group scored far better than the control group ($p = 0.07, d = 0.54$). There is no explainable reason for this occurrence given that the participants were distributed as equally as possible. Thus, the statistical difference indicated by the post-assessment independent t-test for items of moderate complexity is falsely accurate ($p = 0.00, d = 1.20$). What is interesting, though, is that the experimental group demonstrated an increase in scores by 3% at this specific level of complexity while the control group demonstrated a decrease in scores by 8%. This alteration did increase the significance of the difference, but again,
not enough to claim a modality effect. Therefore, it would not be fair to assume that a modality effect occurred simply based on this information.

Another interesting point on the post-assessment results is that there was a statistical difference in scores for items of low complexity, despite a decrease in scores for both groups. The experimental group decreased its scores by 2% while the control group demonstrated a decrease of 10%. This is strange because items of low complexity have relatively low cognitive pressures. If looking only at the post-assessment independent t-test, one could assume that a modality effect occurred for items of low complexity, but there was no improvement in scores.

Though not statistically significant according to the paired sample t-tests, there were improved scores. Mayer (2009) reported that the modality effect occurs at high levels of complexity, but unknown for other levels of complexity. The control group improved its scores for items of high complexity, which is interesting because it is thought that visual-only instruction places too many cognitive pressures to effectively process material that requires higher complexity. The experimental group showed improved scores for items of moderate complexity, as mentioned earlier, and high complexity.

These results are in line with Schnotz’s (2011) argument that a modality effect does not occur under all conditions. Accuracy differences occurred at levels other than high, unlike Moreno’s (2006) conclusion, perhaps because of gender and learning style preferences. While not a significant change, accuracy decreased for the control group possibly because of Sweller’s (1988) split-attention effect through which participants
receiving visual-only learning material are forced to split their attention between text and pictures causing higher cognitive demands to process information.

Moreno (2006) also suggested that the modality principle holds strongest for tasks where learners are not able to control the pace of the presentation of instructional materials. Even though each treatment group received the same amount of instruction time, the experimental group was not able to self-pace the instruction whereas the control group had the implicit opportunity to review the information multiple times within the allotted time.

Furthermore, Paas et al. (2003) postulated that a modality effect may not occur for tasks of low complexity. The thought was that a modality effect occurs when more information needs to be cognitively processed because it is those times of higher levels of cognitive demand when the limited resources within the visual channel of working memory should be freed to decrease potential cognitive overload. This present study suggests that significant differences occur at levels of lower cognitive demands.

It is a concern as to why participants scored lower on items of high complexity as compared to the control group, albeit not at a significant level. Previous studies have shown better accuracy with strong effect sizes for items of high complexity after instruction using the modality principle. Poor performance on items of high complexity could be attributed to fatigue more so than cognitive overload. Participants completed a 20-minute pre-assessment, immediately followed by a form of instruction for 13 minutes, and then finishing with a 20-minute post-assessment. As we know, items of high complexity result in the use of more cognitive load because of the additional intricacies in problem solving as compared to items of low complexity where there is less cognitive
load. Despite the random distribution of complexity throughout the assessments, it would still be of interest to examine the fatigue effect in future studies.

One possible way to have minimized fatigue in this current study would be to administer the pre-assessment on a different day and time; however, maintaining the sample size in this study was critical. Unfortunately, if the pre-assessment were administered on a different day and time, there was risk that the same sample would not continue with the remainder of the study.

The two primary reasons for the pre-assessment in this study were first, to establish complexity levels for the math problems and second, to strengthen the results given the small sample size. Additionally, it was necessary to get a baseline of prior knowledge given Mayer’s (2001) suggestion to establish prior knowledge for a better understanding of cognitive learning processes and meaningful learning. It could be presumed that meaningful learning occurred at least on items of moderate complexity for participants who received instruction using the modality principle.

Another possible reason as to why accuracy did not present significant results could be based on gender with different learning preferences in mind. Previous research suggests that female students prefer single modes of instruction such as the visual-only instruction presented in this current study whereas males prefer multimodal forms of instruction such as the instruction using the modality principle in this current study (Dobson, 2010; Wehrwein, Lujan, & DiCarlo, 2007). Even though this study did not originally consider gender as a covariant, there were 40 females and 8 males in this study. Given that this current study included 83% female participants across both treatment groups, accuracy may have been affected by the negative impact from multimodal
instruction in the experimental group. Students receiving instruction with the modality principle may have not absorbed and processed all the information through the narration whereas those receiving visual-only instruction had the opportunity to revisit details. Future studies should assess gender as a factor when measuring accuracy with the different modes of instruction.

With regard to nursing education, we could present the notion that instruction using the modality principle does aid in accuracy improvement somewhat; however, given that majority of nursing students continue to be female, gender should be considered when instructional designers implement learning material. Because nursing courses are already overwhelmed with rigorous course material, thus leaving little to no room for explicit math instruction, designing learning materials to be used outside of class is possible; however, the modality principle may not be the best method for the females.

**Research Question 2**

The second research question relates to the effects of the modality principle resulting in lower perceived mental effort when compared to visual-only instruction at each level of complexity as indicated by post-assessments. To establish a baseline of information, participants rated their self-perceived levels of mental effort after each math problem on the pre-assessment. For an unexplainable reason, there was a statistical difference in ratings for items of high complexity ($p = 0.00$, $d = 1.05$); the experimental group rated high levels of mental effort. On the post-assessment, however, there were no significant differences indicating that ratings equalized. It should be noted, however, that even though the control group decreased its mental effort ratings for items of low
complexity, the ratings increased for items of moderate and high complexity. On the other hand, the experimental group decreased its ratings of mental effort on all three levels of complexity. Moreover, there was a statistically significant decrease for items of high complexity ($p = 0.02, d = 0.60$). In line with previous research on perceived mental effort (Paas, Sweller, & Van Gog, 2010) and working memory (Baddeley & Hitch, 1974; Miller, 1956), the results in this current study confirm that instruction using the modality principle makes the use of cognitive processes more efficient.

Based on the information between the first and second research questions, we can deduce that even though accuracy scores were not significantly different on the post-assessment for the experimental group, perhaps because of gender and learning style preferences, female learners experience lower cognitive load with multimedia-based instruction when task complexity levels are higher. The assumption is made because 83% of the participants in this study were female.

**Ancillary Analysis**

An ancillary analysis was conducted on confidence rated on a Likert-type scale ranging from 1 (very low confidence) to 5 (very high confidence) (Halford, et al., 2005). The extension beyond Halford et al.’s study was to compare the effects of two instructional formats and to explicitly assess accuracy and perceived mental effort as task complexity increases.

The pre-assessment indicated significantly higher levels of confidence for the experimental group on items of moderate and high complexity. It was initially thought that both treatment groups would measure similarly prior to any form of instruction. The primary explanation to this is the overconfidence effect. Overconfidence effect refers to
someone’s personal bias believing that they have greater ability than in actuality (ref??). In essence, one’s confidence exceeds accuracy. In this case, confidence could be viewed as a characteristic trait such that a person believes they are confident. This may have been the case for the experimental group. It is unclear, though, as to why confidence was not rated similarly between the experimental and control groups given that the participants were quasi-randomly selected. Nonetheless, the post-assessment results may suggest that the participants in the experimental group rated a more realistic perception of confidence as compared to the ratings on the pre-assessment.

Results do not confirm the results of the study conducted by Halford et al. (2005) in which confidence was shown to decrease as complexity increased with visual-only instruction. Paired-sample t-tests showed that where the control group rated significantly higher on items of moderate and high complexity, the experimental group did not demonstrate the same results. In fact, the experimental group decreased its levels of confidence.

In light of the greater percentage of female participants in this study (83%), it seems as though female students feel more confident on their performance after receiving visual-only instruction. Consequently, multimedia instruction when using the modality principle may impede positive results. With that, perhaps another multimedia instruction format could result in better confidence outcomes.

Similar to the reasoning in lack of a modality effect, a possible reason as to why confidence was rated lower for the experimental group is based on learning style preferences. Studies suggest that female students prefer single modes of instruction such as the visual-only instruction presented in this present study whereas males prefer
multimodal forms of instruction such as the instruction using the modality principle in this current study (Dobson, 2010; Wehrwein, Lujan, & DiCarlo, 2007).

Given that this current study included mainly female participants across both treatment groups, confidence may have been affected by the negative impact from multimodal instruction in the experimental group, thus suggesting the interaction between confidence and instruction within the correlation results. Students receiving instruction with the modality principle may have not absorbed and processed all the information through the narration whereas those receiving visual-only instruction had the opportunity to revisit details.

Seeing how a majority of nursing students still remains to be female, future studies should assess gender and learning preference as a factor when measuring confidence with the different modes of instruction. If students are not confident in their performance, despite positive performance outcomes, then self-esteem may indirectly decrease. Lowered self-esteem may alter student self-perceptions of success, thus having a negative impact on math ability and even career path.

**Limitations of the Study**

There were limitations pertaining to this study. In addition to fatigue possibly contributing to low accuracy scores on items of high complexity as discussed with the first research question, three other limitations were of concern in this study: the actual type of instruction using the modality principle, the strength of results given the small sample size, and possible misunderstandings by the participants on the perceived mental effort rating scale.
**Limitation 1**

There are on-going disputes regarding the uses of dynamic versus static images in the instruction using the modality principle. Even though Mayer (2001; 2009) defines the modality principle as converting text to audio and presenting the visual images in either static or dynamic format, his studies primarily integrate and demonstrate stronger results with dynamic images. This current study was designed to eliminate as much static visualization as possible by mimicking Mayer’s approach with audio and dynamic images. Exploring different instruction with variations of dynamic and static images may have provided additional information in this study.

**Limitation 2**

A second limitation in this study was sample size. It would obviously be beneficial to obtain a larger sample size of participants to strengthen the data regarding accuracy, perceived mental effort, and confidence. Many of the previous studies that have tested the modality principle and the cognitive learning processes have been conducted in controlled laboratory settings with large samples sizes. This leads practitioners to question the reliability, and practicality, of results from those studies. Unfortunately, there is very limited research attempting to implement theory into practical settings, specifically within higher education. One difficulty in conducting well-controlled and large investigations in practical settings is obtaining consent from volunteers. For instance, out of a potential 240 students, 48 agreed to volunteer for this current study. Even though the sample size was small, the results garnered could be considered a stepping-stone for future research in a practical classroom setting.
Administering a pre-assessment was one way to combat the small sample size in this current study. Unfortunately, the pre-assessment may have contributed to fatigue as previously discussed when answering the first research question.

**Limitation 3**

The final potential limitation concerns the perceived mental effort rating scale. Despite the best efforts in explaining directions verbally and in text prior to the administration of both pre- and post-assessments, with the opportunity for participants to ask questions, it is possible that the scale did not necessarily measure perceived mental effort in the best possible way. On the other hand, time of day and a fatigue effect may have hindered participant effectiveness.

In general, participants demonstrated a lack of understanding in how to properly rate their perceived mental effort. There were a few math problems that were either incomplete or omitted by the participants writing “I don’t know,” “?,” or “X” in the provided answer box. This was presumably because of the increased level of complexity or fatigue. By doing so, it is believed that the participants assumed that they were expending little to no mental effort when in fact they were experiencing high mental effort because the problem was too difficult for them to complete. In essence, those participants did not put any effort into solving problems. As a result, these few participants rated their perceived mental effort as low rather than high. The intention of this scale is rate perceived mental effort higher if a problem requires more effort or, in turn, may be too difficult to solve. It would be of interest to redesign the mental effort rating scale to accurately measure mental effort. In the case of this current study, it
would be beneficial to redesign the mental effort rating scale to parallel the confidence rating scale so that future correlations can be conducted.

**Research Contribution**

There are four ways this study contributes to the larger body of research: (1) this study provides an easily adaptable instructional format to explicitly instruct math to undergraduate nursing students, (2) it also builds on Mayer’s proposed limitation of the modality principle, (3) the study strengthens the results reported by Halford et al. (2005), and (4) the study contributes additional research on the affective construct of confidence during multimedia learning. By doing so, this study was also able to attempt an implementation of instructional theory into practical settings. It was of interest to see if the cognitive theory of multimedia learning worked in a practical classroom setting. One practical difficulty when conducting studies in classroom settings is obtaining large sample sizes. Despite best efforts to obtain a large sample, a small sample agreed to be part of this study. The results, however, could be used as a basis for future studies to advance the knowledge and understanding of theory in practice.

First, very few studies, and much less current research, examine the impact of instructional design on learning outcomes in undergraduate nursing programs given that explicit math instruction is rarely provided (Costello, 2010). Here, we were able to address that participants receiving instruction using the modality principle do demonstrate better accuracy outcomes than those who receive visual-only instruction. Moreover, this suggests that using a multimedia format to provide an explicit form of instruction is beneficial. This form of instruction is also convenient because the instructor is able to control the level of information provided to students and students can
learn the provided information on their own time without having to aimlessly seek out just any type of math instruction. We also can conclude that students, particularly female students as often still seen within the nursing program, experience less cognitive load. Unfortunately, these students may experience less confidence in their abilities despite positive learning and cognitive outcomes. Additional research on other multimedia formats should occur.

Second, Mayer (2009) suggested limitations on the studies exploring the effects of the modality principle including the lack of research on the modality effect at different levels of complexity. The results do not demonstrate a modality effect based on change scores from the paired-sample t-test. It should be reiterated, though, that the independent t-test results at the moderate level of complexity on the post-assessment for the control group showed decreased scores while the experimental group increased its scores enough to create a significant difference. Replications of this current study are suggested to confirm these results.

Third, this current study was also meant to strengthen and extend the study conducted by Halford, Baker, McCredden, and Bain (2005). Their results suggested that accuracy decreased as task complexity increased regardless of the participants’ implied level of prior knowledge. Prior knowledge was assessed in the pre-assessment in this current study. The researchers assumed that working memory capacity was not as efficient on highly complex tasks than on tasks that were considered low in complexity because participant’s cognitive processes were overloaded. Unfortunately, the researchers did not explicitly measure perceived mental effort as a contributor to decreased accuracy and confidence. The current study explicitly measured perceived
mental effort in conjunction with accuracy. Despite resulting in better accuracy when implementing instruction using the modality principle, perceived mental effort was rated higher. This could indicate that working memory was not as efficient on items of higher complexity as suggested by Halford et al. (2005).

Finally, the ancillary data collected and analyzed on confidence continues to add information to the cognitive-affective theory of learning with media (CATLM; Moreno, 2005). CATLM integrates the motivational facet of learning with multimedia instruction. CATLM is an expansion of Mayer’s (2001) cognitive theory of multimedia learning. Interesting in this matter was that confidence decreased for the experimental group whereas confidence increased for the control group as demonstrated by the paired-sample t-tests. It is suggested that gender and learning preference may have impacted these outcomes.

**Practical Educational Implications**

There were at least three reasons why this study was educationally significant, and thus has practical implications based on the results. First, the results from this study extended Mayer’s previous studies using the modality principle, specifically in acknowledging a potential limitation to the modality principle instructional format such that more research should explore potential modality effects at different levels of complexity. Second, designing instruction using the modality principle may provide a way to overcome the time constraints in nursing courses by providing practical and relevant math instruction via video format that can be accessed outside of class time. Third, instruction using the modality principle may alleviate cognitive load and in turn enhance learning outcomes.
Implication 1

Nurses are expected to successfully demonstrate math skills in their profession, yet math instruction in nursing programs is either non-existent or limited because of time constraints to the already rigorous course material. Possible solutions to overcome inadequate math performance for undergraduate nursing students is to first provide an opportunity for math instruction and second, to successfully design instruction that can easily be adapted into nursing courses without taking away from the already rigorous course load.

Because of the convenient accessibility of instruction using the modality principle through video format, learners could refer to the instruction any number of times and through various technological formats, thus allowing instructors to provide explicit math instruction that could produce better accuracy without taking time away from class time. However, in this study, participants were able to view the video only once whereas the visual-only group was able to repeatedly review information within the allotted time. This may have also impacted accuracy outcomes. Yet, this type of instruction could easily be implemented for remote and online learning environments. By doing so, students are then provided with an opportunity for explicit instruction.

Implication 2

Mayer suggested a limitation on the uses of the modality principle because there is a lack of research on its effects at varying levels of task complexity. This study provided further insight on perceived mental effort and accuracy when using the modality principle at varying levels of task complexity. Previous studies indicated connections between the modality principle and variables such as prior knowledge, working memory
capacity, task complexity, perceived mental effort, and accuracy. Before this study, we knew that the modality principle is beneficial when highly complex learning material is presented, but we did not know if the modality principle is equally effective at all levels of complexity or if its effect changes as complexity increases. Based on this study, we can presume that instruction using the modality principle has a positive impact on accuracy at moderate levels of complexity as well as the already-known high levels of complexity. More studies should be done for levels of low complexity.

**Implication 3**

One way to alleviate cognitive overload is to use an instructional design that uses the modality principle. Traditional instruction takes place through textbook learning (Costello, 2010). Classic textbook instructional formats have the potential of creating cognitive overload because only the visual working memory channel is utilized. Lectures may provide another mode of instruction, but lectures could be presented in at least two ways: audio only or audio with some type of visual graphics. Lectures presented in an audio-only format may also create cognitive overload by utilizing only one working memory channel. Designing instruction using the modality principle in a practical classroom setting results in better accuracy, but it is unclear from this current study if cognitive load decreased. Additional analysis needs to be conducted to assess the difference in perceived mental effort between pre- and post-assessment data for both treatment groups at each level of complexity.

**Directions for Future Research**

Based on the discussion of results and the limitations of this study, there are at least four possible directions for future research after assessing the limitations and results
of this current study: fatigue, sample size, connections among variables, and gender and learning preferences. Given that majority of the participants were female in this study, it would be of most interest to continue exploring the effects from different multimedia instructional formats on female learners.

1. It would be of interest to examine the fatigue effect when studies are conducted in future research. One possibility is to administer a pre-assessment at a different day and time. Unfortunately, with this option, there is a greater risk of participation to decrease as time lengthens.

2. Replicating this study with a larger sample size while maintaining a practical classroom setting and relevant population is highly suggested to strengthen the data regarding accuracy, perceived mental effort, and confidence.

3. Further analysis should be conducted to compare the differences in accuracy, perceived mental effort, and confidence between both treatment groups from pre- to post-assessment at each level of complexity.

4. There should be an examination as to why confidence was rated lower for the experimental group. Possible theories to include are self-efficacy, gender in conjunction with self-esteem, and learning style preferences. It would be of interest to explore other formats of multimedia learning to examine self-perceptions of confidence, particularly for female learners.

**Conclusion**

One goal of this current study was to explore the modality principle as a form of instruction that could be easily adapted into an already rigorous undergraduate nursing course load to explicitly teach math at different levels of complexity. The modality
principle has been shown to demonstrate an effect on levels of high complexity, but its effect has been unknown at other levels of complexity. This study suggests that a modality effect can occur at levels of moderate complexity, but additional studies with larger sample sizes need to occur to confirm or deny this possibility.

Another goal was to explore Mayer’s (2009) suggested limitations of the modality principle in that there is uncertainty if a modality effect can occur at levels of complexity other than high. There were indications that yes, this can happen, confirmation of these results need to occur with larger sample sizes. Moreover, given that the female gender was mostly represented in this study, it would be strongly suggested to replicate this study using female learners.

The third goal was to translate theory into a practical classroom setting by designing instruction using the modality principle to help instruct relevant math problems to undergraduate nursing students. Instructional designers need to properly and effectively design instruction while keeping the cognitive learning processes in mind. One way to do so is by designing instruction through multimedia, specifically the modality principle. Instruction using the modality principle is meant to alleviate cognitive load by balancing information on both visual and verbal channels within working memory. The idea here was to minimize cognitive load when completing math problems of different levels of complexity in hopes of improving accuracy because previous research has indicated successful learning outcomes on better accuracy and lower perceived mental effort with the use of the modality principle. Unfortunately, much of the previous research has been conducted in controlled laboratory settings and not practical settings.
A final goal to this study was to expand the Halford et al. (2005) study where confidence was shown to decrease as complexity increased when instruction was visual-only. The expansion was examining confidence pre and post multimedia instruction. In this case, confidence increased for the visual-only group perhaps because of gender.

Results indicated that while there was better accuracy with the instruction designed using the modality principle, albeit not significantly, perceived mental effort was rated higher than the control group that received visual-only instruction suggesting less cognitive load for items requiring higher cognitive demands. However, confidence was rated higher for the control group suggesting that the modality principle format may have a negative impact on math self-esteem despite positive learning outcomes.
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Appendix A
Pilot Study
Undergraduate nursing students’ performance on algebraic equations: A pilot study
Directions: Complete the equations according to the prompt at the top of each paper. For example, “solve for x” would be one type of direction. You may use each sheet as scratch paper to work out the answer. You may use a calculator. Enter your final answer in the box located in the bottom left hand corner of each sheet for the respective equation.

You have 20 minutes to complete this packet. Complete the equations to the best of your ability.
Solve for $x$

What is $1.67$ of $75$?

Write answer here:
Solve for x

What is 0.87 of 94?

Write answer here:
Solve for x

What is 0.45 of 135?

Write answer here:
Solve for $x$

What is $x$ if $3.2x + 45 = 6.4$?

Write answer here:
Solve for x

What is x if $34.5 - 6.8x = 45x + 19.81$?
Solve for x

What is $x$ if $4.5 - 7.2x = 3.4x - 49.5 + 12.3$?

Write answer here:
Solve for x

What is 35% of 80?

Write answer here:
Solve for x

9 is what percent of 45?

Write answer here:
Solve for x

You have seen 16 of your 20 patients. What percent remains?
A patient’s chart reads that you are to administer 6.95 mls for the 1\textsuperscript{st} hour and 7.61 mls each hour after. By what percent do you increase the dosage?

Solve for x

Write answer here:
Solve for $x$

A nutritionist informs you that 65% of 2000 calories is needed for a 110 pound person. Your patient weighs 76 pounds. What percent of 2000 calories is needed?

Write answer here:
Solve for x

What is $\frac{2}{5}$ of 360?

Write answer here: 175
Solve for \( x \)

What is 1.67 as a fraction?

Write answer here:
Solve for x

What is 12.5% as a fraction?
Solve for x

What is 56% as a fraction?
Solve for x

You are to administer 1 ¾ liters of fluid in 30 minutes.
How many liters in 96 minutes?

Write answer here:
Solve for x

If a person weighs in at 72 kilograms that converts to approximately 159.3 lbs., how many kilograms in 540 lbs.?

Write answer here:
Solve for x
You are preparing to administer 1 \(5/7\) mg of antibiotics for every 2 \(1/3\) mg of saline. How many mg of antibiotics will you administer for 18 \(2/3\) of saline?

Write answer here:
Appendix B
Expert Review Panel
Math instruction using the modality principle: A pilot study
Directions: Thank you for viewing the multimedia instruction format using the modality principle in which dynamic visual images are simultaneously narrated. Please complete the following feedback packet based on the instruction you just viewed. The more feedback, the better.
Audio

Clarity

1 2 3 4 5

O O O O O

Awful Barely Acceptable Satisfactory Outstanding

manageable

Volume

1 2 3 4 5

O O O O O

Awful Barely Acceptable Satisfactory Outstanding

manageable

Additional Feedback?
Dynamic Images

Things to think about – obstructed views? Dark enough images?

1  2  3  4  5

O  O  O  O  O

Awful  Barely acceptable  Satisfactory  Outstanding
manageable

Additional Feedback?
Lighting

1 2 3 4 5

O O O O O

Awful Barely Acceptable Satisfactory Outstanding

Additional Feedback?
Speed/Pacing

1 2 3 4 5

O O O O O O

Awful Barely Acceptable Satisfactory Outstanding

Additional Feedback?
Additional Feedback

Please provide any additional feedback that you see necessary for improvement.
Appendix C
Pre-assessment
Undergraduate nursing students’ performance on algebraic equations: Pre-assessment
Directions for the remainder of the packet:

1. Complete the equations according to the prompt at the top of each paper. For example, “solve for x” would be one type of direction. You may use the front and back of each sheet as scratch paper to work out the answer. Enter your final answer in the blue box located in the bottom left hand corner of each sheet for the respective equation.

2. After each problem will be a 1-9 point scale asking you the amount of effort you placed on the problem where 1 = very, very low mental effort and 9 = very, very high mental effort. Mental effort is defined as “the capacity of effort allocated to the instructional demands” (Paas, 1992, p. 429). In other words, how much effort did you place on solving the problem given the directions?

3. After each problem will be a 1-5 point scale asking you the level of confidence you have in solving the prompt correctly. 1 = very low confidence and 5 = very high confidence (Halford, Baker, McCredden, & Bain, 2005). The “moderate confidence” option is for you feeling neither high nor low confidence.

** The amount of effort you place may be different from the level of confidence you have, and vice versa.

4. You have 20 minutes to complete this packet. Complete the entire packet to the best of your ability.

5. Are there any questions? Once the time starts, you will not be able to ask any questions.
Solve for $x$

What is 0.334 of 235?
In solving the preceding prompt, I invested

<table>
<thead>
<tr>
<th></th>
<th>Very, very low mental effort</th>
<th>Very low mental effort</th>
<th>Low mental effort</th>
<th>Rather low mental effort</th>
<th>Neither low nor high mental effort</th>
<th>Rather high mental effort</th>
<th>High mental effort</th>
<th>Very, very high mental effort</th>
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</table>

How much confidence do I have in solving the preceding problem correctly?

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<tr>
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<th>Very low confidence</th>
<th>Low confidence</th>
<th>Moderate confidence</th>
<th>High confidence</th>
<th>Very high confidence</th>
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<td>O</td>
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<td>O</td>
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<td>O</td>
</tr>
</tbody>
</table>
Solve for x

What is 0.35 of 135?

Write answer here:
In solving the preceding prompt, I invested

1 2 3 4 5 6 7 8 9
0 0 0 0 0 0 0 0 0
Very, very low mental effort
Very low mental effort
Low mental effort
Rather low mental effort
Neither low nor high mental effort
Rather high mental effort
High mental effort
Very high mental effort
Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

1 2 3 4 5
0 0 0 0 0
Very low confidence
Low confidence
Moderate confidence
High confidence
Very high confidence
Solve for x

What is x if 6.4x + 90 = 12.8?

Write answer here:
In solving the preceding prompt, I invested

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    Very, very low mental effort
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    Neither low nor high mental effort
    Rather high mental effort
    High mental effort
    Very high mental effort
    Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

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    Very low confidence
    Low confidence
    Moderate confidence
    High confidence
    Very high confidence
Solve for x

What is x if $69.2 - 13.6x = 90x$?
In solving the preceding prompt, I invested

1  2  3  4  5  6  7  8  9
O  O  O  O  O  O  O  O  O

Very, very low mental effort  Very low mental effort  Low mental effort  Rather low mental effort  Neither low nor high mental effort  Rather high mental effort  High mental effort  Very high mental effort  Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

1  2  3  4  5
O  O  O  O  O

Very low confidence  Low confidence  Moderate confidence  High confidence  Very high confidence
Solve for x

What is x if $9.5 - 14.4x = 6.8x + 99.1$?

Write answer here:

201
In solving the preceding prompt, I invested

1  2  3  4  5  6  7  8  9
O  O  O  O  O  O  O  O  O
Very, very low mental effort
Very low mental effort
Low mental effort
Rather low mental effort
Neither low nor high mental effort
Rather high mental effort
High mental effort
Very high mental effort
Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

1  2  3  4  5
O  O  O  O  O
Very low confidence
Low confidence
Moderate confidence
High confidence
Very high confidence
Solve for x
18 is what percent of 90?

Write answer here:
In solving the preceding prompt, I invested

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How much confidence do I have in solving the preceding problem correctly?

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<td>High confidence</td>
<td>Very high confidence</td>
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Solve for x
What is 70% of 160?

Write answer here:

205
In solving the preceding prompt, I invested

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O O O O O O O O O
Very, very low mental effort Very low mental effort Low mental effort Rather low mental effort Neither low nor high mental effort Rather high mental effort High mental effort Very high mental effort Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

1 2 3 4 5
O O O O O

Very low confidence Low confidence Moderate confidence High confidence Very high confidence
Solve for x

You have seen 32 of your 40 patients. What percent of patients have you seen?

Write answer here:
In solving the preceding prompt, I invested

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Very low mental effort
Low mental effort
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Neither low nor high mental effort
Rather high mental effort
High mental effort
Very high mental effort
Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

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Very low confidence
Low confidence
Moderate confidence
High confidence
Very high confidence
A patient’s chart reads that you are to administer 13.9 mls for the 1\textsuperscript{st} hour and 15.22 mls each hour after. By what percent do you increase the dosage?
In solving the preceding prompt, I invested

1 2 3 4 5 6 7 8 9
O O O O O O O O O
Very, very low mental effort  Very low mental effort  Low mental effort  Rather low mental effort  Neither low nor high mental effort  Rather high mental effort  High mental effort  Very high mental effort  Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

1 2 3 4 5
O O O O O
Very low confidence  Low confidence  Moderate confidence  High confidence  Very high confidence
Solve for $x$

A nutritionist informs you that 85% of 2000 calories is needed for a female weighing 152 pounds. Your patient weighs 110 pounds. What percent of 2000 calories is needed?

Write answer here:
In solving the preceding prompt, I invested

1 2 3 4 5 6 7 8 9

O O O O O O O O O

Very, very low mental effort Very low mental effort Low mental effort Rather low mental effort Neither low nor high mental effort Rather high mental effort High mental effort Very high mental effort Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

1 2 3 4 5

O O O O O

Very low confidence Low confidence Moderate confidence High confidence Very high confidence
Solve for x

What is $\frac{4}{5}$ of 3.6?

Write answer here:
In solving the preceding prompt, I invested

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Very, very low mental effort
Very low mental effort
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Rather low mental effort
Neither low nor high mental effort
Rather high mental effort
High mental effort
Very high mental effort
Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

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Very low confidence
Low confidence
Moderate confidence
High confidence
Very high confidence
Solve for x

What is 56% as a fraction?

Write answer here:
In solving the preceding prompt, I invested

1 2 3 4 5 6 7 8 9

O O O O O O O O O

Very, very low mental effort
Very low mental effort
Low mental effort
Rather low mental effort
Neither low nor high mental effort
Rather high mental effort
High mental effort
Very high mental effort
Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

1 2 3 4 5

O O O O O

Very low confidence
Low confidence
Moderate confidence
High confidence
Very high confidence
Solve for x

You are to administer 3.5 liters of fluid in 1 hour. How many liters in 3 hours and 20 minutes?
In solving the preceding prompt, I invested

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Very, very low mental effort

Very low mental effort

Low mental effort

Rather low mental effort

Neither low nor high mental effort

Rather high mental effort

High mental effort

Very high mental effort

Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

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Very low confidence

Low confidence

Moderate confidence

High confidence

Very high confidence
If a person weighs in at 75 kilograms that converts to approximately 165 lbs., how many kilograms in 245 lbs.? 

Write answer here: 219
In solving the preceding prompt, I invested

![Rating scale for mental effort]

How much confidence do I have in solving the preceding problem correctly?

![Rating scale for confidence]
Solve for x

You are preparing to administer 12.5 mg of saline and 25 mg of antibiotics to a patient. However, the saline comes in 25 mg/1ml and the antibiotics come in 50mg/ml. How many mls of medication will you administer?

Write answer here:
In solving the preceding prompt, I invested

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Very, very low mental effort

Very low mental effort

Low mental effort

Rather low mental effort

Neither low nor high mental effort

Rather high mental effort

High mental effort

Very high mental effort

Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

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Very low confidence

Low confidence

Moderate confidence

High confidence

Very high confidence
Appendix D

Post-assessment
Undergraduate nursing students’ performance on algebraic equations: Post-assessment
Directions for the remainder of the packet:

1. Complete the equations according to the prompt at the top of each paper. For example, “solve for x” would be one type of direction. You may use the front and back of each sheet as scratch paper to work out the answer. Enter your final answer in the blue box located in the bottom left hand corner of each sheet for the respective equation.

2. After each problem will be a 1-9 point scale asking you the amount of effort you placed on the problem where 1 = very, very low mental effort and 9 = very, very high mental effort. Mental effort is defined as “the capacity of effort allocated to the instructional demands” (Paas, 1992, p. 429). In other words, how much effort did you place on solving the problem given the directions?

3. After each problem will be a 1-5 point scale asking you the level of confidence you have in solving the prompt correctly. 1 = very low confidence and 5 = very high confidence (Halford, Baker, McCredden, & Bain, 2005). The “moderate confidence” option is for you feeling neither high nor low confidence.

** The amount of effort you place may be different from the level of confidence you have, and vice versa.

4. You have 20 minutes to complete this packet. Complete the entire packet to the best of your ability.

5. Are there any questions? Once the time starts, you will not be able to ask any questions.
Solve for x

What is 0.11 of 78.3?
In solving the preceding prompt, I invested

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Very, very low mental effort

How much confidence do I have in solving the preceding problem correctly?

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Very low confidence

Low confidence

Moderate confidence

High confidence

Very high confidence
Solve for x

What is 0.117 of 45?
In solving the preceding prompt, I invested

1 2 3 4 5 6 7 8 9

O O O O O O O O O

Very, very low mental effort  Very low mental effort  Low mental effort  Rather low mental effort  Neither low nor high mental effort  Rather high mental effort  High mental effort  Very high mental effort  Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

1 2 3 4 5

O O O O O O

Very low confidence  Low confidence  Moderate confidence  High confidence  Very high confidence
Solve for x

What is x if $12.13x + 30 = 4.27x - 198.1$?
In solving the preceding prompt, I invested

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Very, very low mental effort

Very low mental effort

Low mental effort

Rather low mental effort

Neither low nor high mental effort

Rather high mental effort

High mental effort

Very high mental effort

Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

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Very low confidence

Low confidence

Moderate confidence

High confidence

Very high confidence
Solve for $x$

What is $x$ if $23.067 - 4.53x = 30 + 52.419x$?

Write answer here:
In solving the preceding prompt, I invested

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Very, very low mental effort

Very low mental effort

Low mental effort

Rather low mental effort

Neither low nor high mental effort

Rather high mental effort

High mental effort

Very high mental effort

Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

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Very low confidence

Low confidence

Moderate confidence

High confidence

Very high confidence
Solve for x

What is x if $3.16 - 4.8x = 2.26x - 33.03$?
In solving the preceding prompt, I invested

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Very, very low mental effort

Very low mental effort

Low mental effort

Rather low mental effort

Neither low nor high mental effort

Rather high mental effort

High mental effort

Very high mental effort

Very, very high mental effort

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Very low confidence

Low confidence

Moderate confidence

High confidence

Very high confidence
Solve for x

6 is what percent of 35?

Write answer here:
In solving the preceding prompt, I invested

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Rather low mental effort
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Rather high mental effort
High mental effort
Very high mental effort
Very, very high mental effort

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Very low confidence
Low confidence
Moderate confidence
High confidence
Very high confidence
Solve for x

What is 35% of 54?

Write answer here:
In solving the preceding prompt, I invested

1 2 3 4 5 6 7 8 9

O O O O O O O O O

Very, very low mental effort Very low mental effort Low mental effort Rather low mental effort Neither low nor high mental effort Rather high mental effort High mental effort Very high mental effort Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

1 2 3 4 5

O O O O O

Very low confidence Low confidence Moderate confidence High confidence Very high confidence
Solve for x

Of 150 patients in two weeks, 108 were considered successful. What percent of patients were considered not successful?

Write answer here:
In solving the preceding prompt, I invested

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Rather high mental effort
High mental effort
Very high mental effort
Very, very high mental effort

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Very low confidence
Low confidence
Moderate confidence
High confidence
Very high confidence
Solve for x

A patient’s chart reads that you are to administer 4.63 mls for the 1st hour and 5.07 mls each hour after. By what percent do you increase the dosage?

Write answer here:

242
In solving the preceding prompt, I invested

1 2 3 4 5 6 7 8 9
O O O O O O O O O
Very, very low mental effort Very low mental effort Low mental effort Rather low mental effort Neither low nor high mental effort Rather high mental effort High mental effort Very high mental effort Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

1 2 3 4 5
O O O O O
Very low confidence Low confidence Moderate confidence High confidence Very high confidence
Solve for x

A toxicologist informs you that 0.05ppm is the maximum amount of hexavalent chromium allowed before negative health symptoms can be attributed to its ingestion. A patient enters with 0.58ppm in the system. By what percent is the patient over the limit?

Write answer here:
In solving the preceding prompt, I invested

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<td>Very, very low mental effort</td>
<td>Very low mental effort</td>
<td>Low mental effort</td>
<td>Rather low mental effort</td>
<td>Neither low nor high mental effort</td>
<td>Rather high mental effort</td>
<td>High mental effort</td>
<td>Very high mental effort</td>
<td>Very, very high mental effort</td>
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How much confidence do I have in solving the preceding problem correctly?

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<td>Low confidence</td>
<td>Moderate confidence</td>
<td>High confidence</td>
<td>Very high confidence</td>
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</table>
Solve for x

You are asked to place an order for strips of adhesive tape that are 3 3/5 inches long. Rolls of tape come in 200 feet. How many strips of adhesive tape can you get in six rolls?

Write answer here: 246
In solving the preceding prompt, I invested

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Very, very low mental effort
Low mental effort
Rather low mental effort
Neither low nor high mental effort
Rather high mental effort
High mental effort
Very high mental effort
Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

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Very low confidence
Low confidence
Moderate confidence
High confidence
Very high confidence
Solve for x

What is 42% as a fraction?
In solving the preceding prompt, I invested

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Very, very low mental effort
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Rather high mental effort
High mental effort
Very high mental effort
Very, very high mental effort

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Very low confidence
Low confidence
Moderate confidence
High confidence
Very high confidence
Solve for x
A saline solution calls for 1 5/6 liters of water and \( \frac{3}{4} \) liters of saline. How many liters of solution will there be total?

Write answer here: 250
In solving the preceding prompt, I invested

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Very, very low mental effort    Very low mental effort    Low mental effort    Rather low mental effort    Neither low nor high mental effort    Rather high mental effort    High mental effort    Very high mental effort    Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

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Very low confidence    Low confidence    Moderate confidence    High confidence    Very high confidence
Solve for x

A 3 \(\frac{1}{4}\) cup of cereal provides 125 calories. Approximately how many calories will be provided by a 1 \(\frac{2}{3}\) cup serving of cereal?

Write answer here: 252
In solving the preceding prompt, I invested

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Very, very low mental effort

How much confidence do I have in solving the preceding problem correctly?

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Very low confidence

Low confidence

Moderate confidence

High confidence

Very high confidence
Solve for x

You are preparing to administer 25 mg of saline and 50 mg of antibiotics to a patient. However, the saline comes in 50 mg/2ml and the antibiotics come in 100mg/ml. How many mls of medication will you administer?

Write answer here:
In solving the preceding prompt, I invested

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very, very low mental effort

Very low mental effort

Low mental effort

Rather low mental effort

Neither low nor high mental effort

Rather high mental effort

High mental effort

Very high mental effort

Very, very high mental effort

How much confidence do I have in solving the preceding problem correctly?

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Very low confidence

Low confidence

Moderate confidence

High confidence

Very high confidence
Appendix E
MERS_Paas (1992)
The Paas (1992) Cognitive Load rating scale

<table>
<thead>
<tr>
<th>In solving or studying the preceding problem I invested</th>
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<tbody>
<tr>
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