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The Effects of Modality and Gender on Learning the Algebra Concepts *Functions* and *Function Notation* among University Undergraduate Students

By

Ali Alhramelah

A dissertation

submitted in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy in the Department of Instructional Design

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Committee Approval

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September 27, 2017

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RE: regarding study number IRB-FY2018-31: The Effects of Modality and Gender on Learning the Algebra Concepts Functions and Function Notation among University Undergraduate Students

Dear Dr. Alhramelah

I agree that this study qualifies as exempt from review under the following guideline: Category 1. Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
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Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

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Dedication

I dedicate this great work and this wonderful success to my parents. They have supported me with everything I need and encouraged me to complete this project. They were busy with me during all the phases of this work. They were usually asking about the progress in the research phase. They constantly communicated me to follow up all the work in my research. Their recommendations for me to be ambitious, diligent, and patient. Indeed, they were a great supporter for me to achieve this scientific success.

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It was a long scientific journey. Seeking knowledge is the best of times and for the sake of it, the sacrifices are made. I do believe that the quest for knowledge is a path towards advancement and creativity. Such a scientific achievement would not have been possible without the support of members represented in the research committee headed by Dr. David Coffland, the main supervisor of my dissertation. I am grateful for the feedback, support, and guidance of Dr. David Coffland during all the time of this research.

I would like to thank the distinguished members of the Committee: Dr. Dotty Sammons, Dr. Corey Schou, Dr. Cory Bennett, and Dr. Zackery Heern for their support in carrying out this research project. Their feedback and directions on the research had a profound impact on the completion of this research. I also thank all faculty members in the Department of Instructional Design and in the College of Education at Idaho State University.

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Abstract

This study was conducted to examine the effects of modality across gender on undergraduate student achievement when learning Algebra concepts. Cognitive Load Theory (CLT) and Cognitive Theory of Multimedia Learning (CTML) provided a framework for this study to describe in depth the concept of the modality principle. Participants were undergraduate students who were enrolled into the Elementary Algebra or the Intermediate Algebra courses for Fall 2017. The total number of participants was 108 students (74 females and 34 males). Participants joined the study as volunteers.

The experiment was delivered completely online. It included two different treatments: (a) graphics and narration (GN) and (b) graphics and written text (GT). Participants were first blocked by gender and then randomly assigned into one of these two treatments. The duration of the treatment was two weeks. The dependent variable was student achievement on the posttest. The data included all participants' answers on the posttest from both groups paired with their gender. A 2x2 factorial ANOVA design was used to analyze the data in order to answer the research questions.

The results of this study showed there was no significant main effect for either the modality principle or gender on student achievement. Also, no significant interaction effect between modality and gender was found on student achievement. However, the results of the independent t-test revealed a significant difference between students from the Intermediate Algebra course and those from the Elementary Algebra course, favoring the Intermediate Algebra students.

The results of this study were in contrast to the hypotheses of this research, which

were based on previous literature. The fact that the sample of this study was drawn from two different Algebra courses may have increased the variance. Also, the number of female students was more than the male students in this study. These facts about the sample of this study may have obscured otherwise statistically significant results.

CHAPTER I

Introduction

Developing instruction for learners in the educational field should be well designed as an effective approach (Morrison, Ross, Kalman, & Kemp, 2011). The role of instructional designers is to design and facilitate the learning processes and be aware of the development of technological tools and how these tools can enhance learning (Reiser & Dempsey, 2012). The growth of technological tools plays an important role in educational fields, especially in online learning environments (Davidson-Shivers & Rasmussen, 2006).

Online learning provides opportunities for learners to get more convenient and easier access to the educational process (Reiser & Dempsey, 2012). A survey was conducted by the Babson Survey Research Group to track online education in the United States indicated that "the observed growth rate from 2013 to 2014 of the number of students taking at least one distance course was 3.9%, up from the 3.7% rate for the previous year" (Allen, Seaman, Poulin, & Straut, 2016, p. 4). These results provide evidence of the continuing growth of online learning and indicate that the increased demand for online learning is a relative in many institutions. Therefore, the implementation of online learning is a significant factor in educational expansion and new access to education for many people, a fact which could create an environment that learners can explore, employ, and experiment with the knowledge (Allen et al., 2016).

Designing instruction to facilitate learning in an online environment is a challenging task (ChanLin, 2009). The research identified that Working Memory (WM) is very limited in the duration of processing information and the capacity of storing information (Miller, 1956). Therefore, the challenge is designing instructional presentations that do not exceed the processing limits of the human mind (Sorden, 2005). This is particularly challenging in the design of multimedia instruction that involves the synchronous presentation of pictures and words (Clark & Mayer, 2011). Fortunately, the load on the human mind can be reduced by presenting information in ways that equally distribute the load between the visual and the auditory channels in WM (Mayer, 2005). For example, the load on the visual channel can be reduced by converting on-screen text to a narration, thereby shifting the load from the visual to the auditory channel.

Using both the auditory and visual channels of WM can play an important role in reducing learners' cognitive load (Clark & Mayer, 2011). Efficient use of WM resources is central to the modality principle, which recommends presenting words on the multimedia presentation as speech rather than on-screen text (Clark & Mayer, 2011). In other words, the modality principle is to present information in a mixed mode, visual and auditory (Low & Sweller, 2005). The modality principle has been shown to improve learning by reducing cognitive load (Clark & Mayer, 2011). This principle is based on Cognitive Load Theory (CLT) and Cognitive Theory of Multimedia Learning (CTML), which explains how to reduce the cognitive load by using both channels (verbal and visual) in WM to process information (Mayer, 2005).

Many studies have shown that there is a positive effect of modality on learning different materials (Mayer, 2005). However, a review of the literature found just a few studies examining the modality effect on mathematics learning (Ginns, 2005; Reinwein, 2012). Based on the literature reviews of these studies, it was recommended to examine the modality effect on mathematics learning (Atkinson, 2002; Jeung, Chandler, & Sweller, 1997; Mattis, 2012; Mousavi, Low, & Sweller, 1995). Besides the importance of investigating the effect of modality on mathematics learning, Mattis (2012) recommends examining the effects of gender across modality on learning mathematics concepts.

Purpose of the Study

This present study intended to investigate the effectiveness of applying modality across gender on learning mathematics concepts in higher education. This study included two different modes of mathematics instruction about "Introduction to Functions and Function Notation" for undergraduate students. These modes were graphics and written text (GT), which represents non-compliance with the modality principle, and graphics and narration (GN), which represents the modality principle. By using the modality principle, both verbal and visual channels can be active to reduce the cognitive load throughout the learning process. Both modes of instruction were delivered as an online course using the institute's learning management system (Moodle). In addition, the gender effect across modality on student achievement is still a significant factor that should be examined (Flores, Coward, & Crooks, 2010), especially with mathematics information (Mattis, 2012). Therefore, the purpose of this study was to test the effects of modality across gender on mathematics learning when teaching an "Introduction to Functions and Function Notation" to undergraduate students at an intermountain west public university.

Research Questions

The research questions derived from the study purpose are:

1. Do modality and gender have effects on student achievement among undergraduate students learning mathematics concepts?

    1.1 Is there a main effect of modality on student achievement, as measured by the scores of students, who learn an "Introduction to Functions and Function Notation" through graphics and narration (GN), as compared to those who learn through graphics and written text (GT)?

    1.2 Is there a main effect of gender on student achievement between those who learn an "Introduction to Functions and Function Notation"?

    1.3 Is there an interaction effect on student achievement due to the combination of modality (GT – GN) and gender (M – F)?

Research Design

Since the purpose of this study was to investigate the effects of modality across gender on mathematics learning, this study used a quantitative method by applying the experimental design. The researcher wanted to use the randomized block design because there were two independent variables with two different levels for each one and participants were blocked by gender (Kirk, 1982). Within blocks (M – F), participants were randomly assigned into two different treatments (GT – GN). Based on the previous research questions, the effects of two types of instruction with gender on student achievement were assessed using a 2x2 factorial ANOVA.

The mathematics concept that was taught in this study is the "Introduction to Functions and Function Notation". This experiment was delivered through the institute's learning management system (Moodle) as an online course. This study included two different treatment conditions (the instructional intervention phase): (a) students who learn through graphics and written text (GT) and (b) students who learn through graphics and narration (GN). For the GT group, both the text and the graphic were simultaneously displayed on the computer screen. However, for the GN, the graphic was presented on the computer screen, whereas the text was narrated and not displayed.

Since a 2x2 factorial ANOVA design was used in this study, participants were first blocked by gender. Within these blocks, the participants were randomly assigned to different instruction modes. By carrying out this action, this study provided information about the implementation of the modality principle. In addition, information gathered showed some explanations about gender differences in mathematics learning as it is discussed in Chapter IV.

Definitions of Terms

Cognitive load theory. It is a psychology theory, which emphasizes the role of a human cognitive architecture in learning (Sweller, Van Merrienboer, & Pass, 1998). This theory states that WM can only hold a finite amount of information, and that different types of load can create higher or smaller burdens on WM. Cognitive load was classified to three types: intrinsic, extraneous, and germane (Sweller et al., 1998). This theory also proposed several guidelines for designing instructional materials with consideration of WM limitations.

Cognitive theory of multimedia learning. It provides an illustration on how people learn by using words and pictures, and it is based on three assumptions: dual-channel processing, limited memory capacity, and active processing (Mayer, 2001, 2005). This theory also presents several principles for designing multimedia instructions, which may lead to reducing the cognitive load.

The modality principle. It is an instructional design principle that can increase learning by presenting information in different modes, visual and auditory, which represent words as speech rather than on-screen text on the multimedia presentation (Clark & Mayer, 2011; Low & Sweller, 2005). Using both visual and auditory channels in learning may reduce the cognitive load and increase the capacity of WM by activating each channel of WM rather than just one (Moreno & Mayer, 1999).

Working memory. It "refers to a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning" (Baddeley, 1992, p. 556). WM is very limited in the memory capacity and the duration of processing the information (Driscoll, 2005; Cowan, 2001; Miller, 1956).

Dual-channel processing. It means that "Humans possess separate information processing channels for visually represented material and auditory represented material" (Mayer, 2005, p. 33). The visual channel is responsible for processing the information that is presented to the eyes and the auditory channel is processing the presented information through the ears (Mayer, 2001, 2005).

Limited memory capacity. It indicates that "Humans are limited in the amount of information that can be processed in each channel at one time" (Mayer, 2005, p. 35).

The capacity of WM can only hold a small amount of information at a certain time like seven plus or minus two items, such as meaningful units of words, letters, and numbers (Miller, 1956).

Active processing. It shows "Humans actively engage in cognitive processing in order to construct a coherent mental representation of their experience" (Mayer, 2005, p. 36). Active processing requires learners to select, organize, and integrate selected material with prior knowledge from long-term memory (Mayer, 2005).

Limitations

Limitations are the threat to the internal validity. The internal validity means "the inferences about whether the changes observed in a dependent variable are, in fact, caused by the independent variable(s) in a particular research study rather than by some extraneous factors" (Ary, Jacobs, & Sorensen, 2010, p. 272). Campbell and Stanley (1963) classified eight extraneous factors that can be threats to the internal validity. These threats include history, maturation, testing effect, instrumentation, statistical regression, selection bias, mortality, and selection-maturation interaction. However, the use of a control group in this study would minimize the effects of history, maturation, and testing effect (Ary et al., 2010; Slavin, 2007). In addition, the use of random assignment for participants to the different treatments in this study would limit the effects of statistical regression, selection bias, and selection-maturation interaction (Ary et al., 2010; Slavin, 2007).

The design of this study did not have a pretest and therefore participants were not selected based on any knowledge or characteristics. The trait of the participants leading to inclusion in the sample was their enrollment in the Intermediate Algebra (MATH 1108) or the Elementary Algebra (MATH 0025) courses. Participants were 18 years old or above; therefore, students below 18 years of age were not included in this study. Since this study also examined the gender (female and male) difference in mathematics learning, any other considerations of gender except female and male were excluded from the data analysis. It is assumed that students have a similar level of knowledge regarding the concept of functions and function notation since they joined these courses. Therefore, the absence of the baseline test would reduce the possibility of the statistical regression effect (Ary et al., 2010).

The selection-maturation interaction effect can be affected by the time of the study (Slavin, 2007). Ary et al. (2010) indicated that participants may get older, smarter, taller, or more fatigued during a long study, and these may affect their performance on the dependent variable measure. However, the participants of this study were adult and the length of this study was short (around two weeks). Since the duration of this study was short, the effect of the selection maturation was assumed to be minimal (Ary et al., 2010; Slavin, 2007).

The effect of instrumentation on the internal validity refers to the difference or changes in the instrument used during the study including the type of measuring instrument, the difficulty level, the scores, and differences in the test administration (Ary et al., 2010). This effect can be controlled in this study because the test measurement was electronic and objectively graded.

The mortality effect refers to the loss of participants from any group during the experiment session (Slavin, 2007). This study took place after the deadline for dropping out from courses and that may have minimized the effect of this potential limitation. In addition, the timing of this study was short and that may motivate students to continue the experiment. Also, the short period of study might limit the possibility of students lost due to illness or moving away.

Beside the previous extraneous factors, Cook and Campbell (1979) also identified three more factors that may threaten the internal validity. These factors are experimenter effect, subject effects, and diffusion.

Experimenter effect refers to unintentional effects of characteristics of the teacher or experimenter on the study (Ary et al., 2010; Slavin, 2007). The research design of this study eliminated all the sources of differences between experimental and control groups except the treatments themselves. Additionally, both treatments of two groups were delivered via an asynchronous online environment, and there was no effect of the teacher or experimenter's characteristics on the study. Therefore, the experimenter effect on the performance of subjects in this study would be limited.

Subject effects indicate that a tendency of subjects in an experimental group (Hawthorne effect) or a control group (John Henry effect) to increase their efforts over the normal because they know they are in an experiment and want to be better (Ary et al., 2010). All participants in both groups were informed that they are not in a competition with each other, and so they did not need to have a special effort to master the materials of their treatments. Participants also were informed that they should have their typical and normal effort while they are in the study.

Diffusion happens when subjects or the teacher of the experimental group speak to subjects or the teacher of the control group about the treatment in such way to influence the performance of subjects on the dependent variable (Ary et al., 2010). To overcome this limitation, all subjects in both groups were asked to focus on their treatments and not communicate any information about the treatments with each other. Moreover, no teachers were involved with either the experimental group nor the control group because both treatments of two groups were designed to be taught online asynchronously.

Delimitations

Delimitations are considered as threats to external validity. External validity indicates “the extent to which the findings of a study can be generalized to other subjects, settings, and treatments” (Ary et al., 2010, p. 292). All participants in this study were from the study university; however, they may not be representative of the larger mathematics students’ population. This is a selection-treatment interaction (nonrepresentativeness), which may threaten the external validity (Slavin, 2007). Therefore, the ability to generalize the results of this study may be limited to similar environments.

Another threat to the external validity is artificiality, which means a study is conducted in a special setting (Slavin, 2007). This study was delivered online and all students were asynchronously participating in this study through the online tools provided in the learning management system (Moodle). An asynchronous learning environment is different than a synchronous learning environment, and the online environment, in general, is different than other learning environments, such as a traditional classroom. Thus, the findings of this study may be different than another one that would be conducted in a different setting, and it might not be possible to generalize the findings to another environment with different settings.

The chosen content for this experiment may be considered as a threat to the external validity. The "Introduction to Functions and Function Notation" was selected for this study from the contents of the Intermediate Algebra course. This course discusses different topics of Algebra and the concept of the selected topic is about functions and notation. Some students may have difficulty with this topic, while others may not feel challenges when studying this concept. With this point in mind, the results of this study may limit the generalizability of the results.

Moreover, the length of this experiment was short, and this might be considered as another delimitation. The selected topic was not long and it needed a short period of time to be taught to students. However, the duration of this study may affect the generalizability of the results.

Significance of the Study

This study examined the effects of modality and gender on student achievement when learning mathematics content, specifically functions and function notation. With the lack of prior research in this area, the results of this study may help instructors to understand the implementation of the modality principle when teaching mathematics to undergraduate students. It may provide an approach for mathematics instructors to teach mathematics concepts by using multimedia presentation principles. Furthermore, this study could offer a solution for those students who have difficulty with mathematics problems, which they might be better able to comprehend through the multimedia learning. The results of this study may provide more explanation about gender differences in mathematics learning in online environments. Moreover, the results may help instructional designers to understand how the modality principle relates to gender-based learning preferences, in order to design appropriate instructions.

CHAPTER II

Literature Review

Applying the modality principle requires an in-depth understanding of the rationale and theories that undergird this principle (Mayer, 2005). Cognitive Load Theory (CLT; Sweller, Van Merrienboer, & Pass, 1998) and Cognitive Theory of Multimedia Learning (CTML; Mayer, 2001, 2005) provide the theoretical foundation for the modality principle. They draw on some theories such as Baddeley's (1986) model of working memory and Dual coding theory by Paivio (1986). These theories are related to the modality principle, but they have been combined recently into CTML. Before studying these theories, it is essential to investigate the characteristics of Working Memory (WM). Therefore, the following sections will discuss the characteristics of WM, then investigate the CLT and the CTML, including Baddeley's (1986) model of working memory and Dual coding theory, as a theoretical framework for this study.

The literature review identified various research articles related to the implementation of the modality principle on learning and gender differences in mathematics learning. These research articles have been reviewed to understand how the research was designed as well as to find out what research questions have been asked. As a result of this literature review, the gap in this research was identified as discussed later in this chapter.

Terms related to Cognitive Load Theory, Cognitive Theory of Multimedia Learning, Working Memory were used to identify research about the theoretical framework for this study. Other search terms include multimedia principles, the modality principle on learning were also used to search about the effect of modality on learning. In addition, terms such as gender differences in mathematics learning were used to review what the research has been found about gender differences in mathematics learning.

The Characteristics of Working Memory

Research has explored the characteristics of WM, which provides guidance for instructional designers to design and provide organized instruction (Jong, 2010). WM is "the stage at which further processing is carried out to make information ready for long-term storage or a response" (Driscoll, 2005, p. 75). WM is very limited in the duration of processing the information: it can hold information for a limited amount of time—between 20 to 30 seconds (Driscoll, 2005). Therefore, WM is fragile because information is lost if not well learned. Another characteristic of WM is the limitation of memory capacity (Driscoll, 2005). WM can only hold a small amount of information at a time. The capacity of WM contains seven items, plus or minus two, such as meaningful units of words, letters, and numbers (Miller, 1956). Cowan (2001) contradicted Miller's estimation of WM capacity. Cowan (2001) proposed that WM capacity has three to five items. However, both estimations of WM capacity are similar, which indicate that the limitation of WM capacity is real (Cowan, 2001). It is evident that WM plays a critical role in learning; however, it can only process a certain amount of information during the learning process. The characteristics of WM and its function should be recognized by teachers and instructional designers, in order to provide organized instruction and avoid cognitive overload.

Cognitive Load Theory

Cognitive Load Theory (CLT) aims to provide guidelines for instructional designers regarding how information should be presented to learners for an effective learning (Sweller et al., 1998). This theory assumes that human cognitive architecture includes a limited capacity of WM to process information and unlimited long-term memory to store large information in schematic forms (Sweller et al., 1998). Knowledge is constructed into schemas in long-term memory (Sweller et al., 1998). Sweller (1994) defined a schema as "a cognitive construct that organizes the elements of information according to the manner with which they will be dealt" (p. 296). The concept of schemas, which can be linked to the concept of a chunk (Miller, 1956), determines how new information is controlled and dealt with (Sorden, 2005). In other words, major functions of a schema are to provide a mechanism for the organization and storage of new information as well as reduce cognitive load in WM (Sweller et al., 1998). With this knowledge about information processing in human mind, instructional designers need to be more careful on how to present information to the learner in a way to avoid cognitive load.

According to Sweller et al. (1998), WM load can be affected by the intrinsic nature of the information or by the way of presenting the information to learners. Sweller et al. (1998) categorized cognitive load to three types: intrinsic, extraneous, and germane. The first type, intrinsic cognitive load, is related to the complexity of materials that need to be learned (Sweller, 1994). Intrinsic cognitive load can be determined by element interactivity: the interaction among the task elements needing to be learned (Sweller, 1994). Sweller et al. (1998) stated that "an element is anything that has been or needs to be learned, most frequently a schema" (p. 259). Therefore, if task elements do not interact and they can be learned in isolation, intrinsic cognitive load is low because this task has low element interactivity (Sweller, 1994; Sweller et al., 1998). In this case, the elements of low interactivity tasks can be well learned without holding more elements in WM at the same time (Sweller et al., 1998). In contrast, high element interactivity tasks contain elements that cannot be learned in isolation and they need to be processed simultaneously in WM (Sweller, 1994; Sweller et al., 1998). These elements heavily interact and this interaction leads to increase the load of WM, which is, in this case, intrinsic cognitive load (Sweller, 2010). The level of interaction among the task elements being learned can determine intrinsic cognitive load. Thus, intrinsic cognitive load cannot be manipulated or influenced by instructional designers (Sorden, 2005; Sweller et al., 1998).

Extraneous cognitive load is caused by inappropriate instructional design strategies, such as presentation methods, the design of activities, or the organization of information (Sweller et al., 1998). In addition, Sweller (2010) suggests that "element interactivity is the major source of working memory load underlying extraneous as well as intrinsic cognitive load" (p. 125). If the modification of element interactivity affects the knowledge being learned, then it is intrinsic cognitive load, but when element interactivity can be reduced without modifying the learned knowledge, the load is extraneous (Beckmann, 2010). Therefore, extraneous cognitive load should be minimized as much as possible to reduce WM load. Instructional design for new information should be based on the limitations of WM and CLT to produce an effective learning experience.

Finally, germane cognitive load refers to resources of WM that are relevant to the construction and processing of appropriate schemas (Sweller et al., 1998). Sweller (2010) stated that “if intrinsic cognitive load is high and extraneous low, germane cognitive load will be high because the learner must devote a large portion of working memory recourses to dealing with the essential learning materials” (p. 126). Therefore, instructional design that increases germane cognitive load and at the same time decreases extraneous cognitive load will maintain learners’ attention on the processes that are relevant to learning and construction of new schemas (Sweller et al., 1998).

In general, CLT aims to provide instructional design with a framework on how to design an instruction (Sweller et al., 1998). Extraneous cognitive load can be altered and influenced by instructional design (Sweller, 2010), and so it should be reduced. Research on CLT discussed several instructional techniques for reducing cognitive load (Sweller, 1994; Sweller et al., 1998). For multimedia presentations, Sweller et al., (1998) stated that cognitive load can be reduced by presenting information via dual modalities (visual and auditory). They argued that processing information through both the visual and auditory channels – the modality principle (Clark & Mayer, 2011) – can reduce cognitive load and increase limited memory capacity. The modality principle was derived from the spilt-attention effect, which occurs when two or more sources of materials need to be learned simultaneously for a meaningful learning (Sweller et al., 1998). Since materials from two or more sources cannot be understood in isolation, it is much better to provide information visually (e.g. graphics) with an audio narration of related information (supporting or explanation information) (Sorden, 2005). For the use of the modality principle in multimedia learning, it is more significant to examine Cognitive Theory of

Multimedia Learning (CTML), which is a recent theory that provides more explanation about the concept of the modality principle (Clark & Mayer, 2011).

Cognitive theory of multimedia learning. The purpose of CTML was to comprehend the use of words and pictures to improve human learning (Mayer, 2001, 2005). Multimedia instruction should be designed based on the ways people learn, and CTML can provide guidance by explaining how people learn using words and pictures (Figure 1). Mayer (2001, 2005) identified three assumptions underlying CTML: dual-channel processing, limited memory capacity, and active processing.

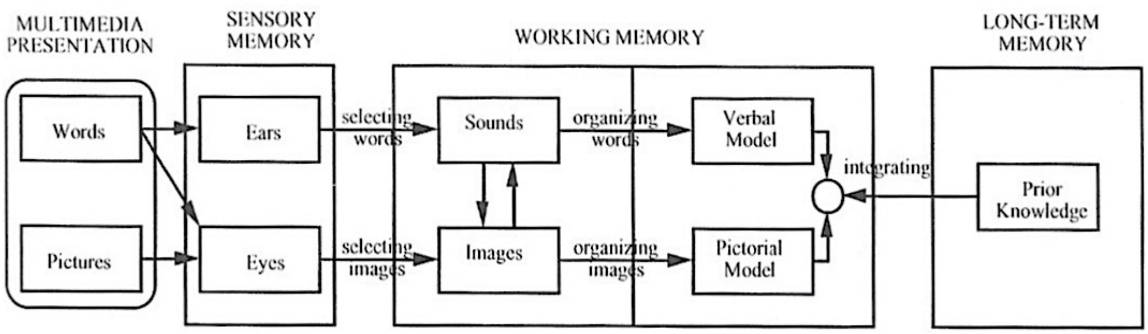


Figure 1. Cognitive theory of multimedia learning (Mayer, 2005).

Dual-channel processing. According to Mayer (2001, 2005), this assumption states that the human mind contains two separate channels for processing visual/pictorial and auditory/verbal information. The visual/pictorial channel is responsible for processing the information that is presented to the eyes, such as screen text, animation, or pictures (Mayer, 2005). The auditory/verbal channel is processing the presented information through the ears, such as nonverbal sounds or narration (Mayer, 2005). These two channels are different from each other, and the difference can be clarified based on two criteria: presentation modes and sensory modalities (Mayer, 2001). The presentation mode is classified as the presented information into verbal, such as spoken or printed words, or non-verbal, such as pictures, videos, animation, and background sounds.

The concept of the presentation modes is associated with Paivio's (1986) model: Dual-Coding Theory. Dual coding theory was developed by Paivio (1986) to provide an equal weight to verbal and non-verbal processing. It assumes that there are two cognitive subsystems in WM. The first subsystem is called "Imagens", which is responsible for the representation and processing of nonverbal objects and events (images). The second one is "Logogens" that processes the verbal entities (languages) (Paivio, 1986).

Mayer (2005) stated that the sensory modalities criterion distinguished the presented information based on whether this information is presented to the eyes or the ears. According to this criterion, the visually presented materials (e.g., images, video, animation, or on-screen text) can be processed by one channel, and the auditory presented materials (e.g., spoken words, or background sounds) can be processed by the other channel. Although Baddeley's (1986) model of working memory is related to the principles of the sensory modalities, his theory is implemented more frequently in the limited capacity assumption, which is explored in the next section.

Limited memory capacity. The amount of information available to WM for processing in each channel is limited (Mayer, 2001, 2005). The concept of limited capacity is associated with Baddeley's (1986) model of WM, which was derived from the previous concept of short-term memory (STM). Atkinson and Shiffrin (1968) developed the STM model; it aims to describe how information is processed in STM and how this information can be transferred to long-term memory. The term STM became WM in Badderley's (1986) model, which focused on understanding the elements of WM and how they work together. Baddeley's (1986) model contains four components: the phonological loop, the visuo-spatial sketchpad, the central executive, and the episodic buffer. This model provides an explanation about the aspects of WM and how these elements are related to each other to process the information. The components of this model will be elaborated in the following paragraphs.

First, the role of the phonological loop component is to process sounds in WM; it is responsible for speech-based information (Baddeley, 2000). During a learning situation, all sounds, such as learning new vocabulary, remembering instructions, or listening to narration, will be processed through the phonological loop. However, as discussed earlier, the storage of this component is limited in capacity: it can hold information for only 20 – 30 seconds.

Next, the visual and spatial information is processed by the visuo-spatial sketchpad (Baddeley, 1992). The visuo-spatial sketchpad component is used for navigation: when a person wants to move to another location, the visuo-spatial sketchpad is stimulated (Baddeley, 2003). Moreover, people use this component to process multi-activities, such as puzzles, mazes, and games (Baddeley, 1992).

Thirdly, the central executive is assumed to be an attentional-controlling system (Baddeley, 1992). The central executive function is to coordinate information from other components, but it also has limited capacity (Baddeley, 1992). Although the central executive is considered the most important part of WM, its functions are still not fully understood (Baddeley, 2003).

The final component, the episodic buffer, was added by Baddeley to the original model 25 years after the publication of his original model (Baddeley, 2000). This component is controlled by the central executive and has limited capacity. The function of the episodic buffer is to store information in different codes; this combines information from the other memory components: the phonological loop, the visuo-spatial sketchpad, and long-term memory (Baddeley, 2000). The episodic buffer serves as the connection between WM and long-term memory (Baddeley, 2000).

Baddeley's (1986) model provides a valuable illustration of the components of WM and how they are related to each other. This model explains that human mind has two different channels: visual and auditory, as discussed in the first assumption, and each channel is limited in capacity. Understanding these limitations of WM, stimulate instructional designers to come over these limitations by detecting beneficial strategies, which will be discussed later after the next section.

Active processing assumption. Based on Mayer (2001, 2005), people should be engaged in the cognitive processing to construct a meaningful learning experience. To achieve this goal, Mayer stated that learners should learn three processes for active learning: selecting relevant material, organizing selected material, and integrating selected material with prior knowledge from long-term memory (Mayer, 2005). Below is a detailed explanation of these processes.

First, selecting relevant material requires learners to pay more attention to applicable words and images in the multimedia message. Clark and Mayer (2011) stated that "multimedia presentation can encourage learners to engage in active learning by mentally representing the material in words and in pictures, and by mentally connections between the pictorial and verbal representations” (p. 71).

Second, organizing selected material assists learners to explore the elements in the multimedia message, and then build the relationships among them in a meaningful concept (Mayer, 2005). The learning environment should be structured to challenge learners’ thinking to motivate them to be able to construct their new knowledge in an effective way (Schunk, 2012). Piaget’s perspective encouraged teachers to understand the development processes of children minds, as he believes that the fundamental process of learning is discovery (Driscoll, 2005). Based on Piaget’s perspective, learners can discover the new knowledge, explore their relationships, and construct their knowledge.

Finally, integrating selected material with the prior knowledge step focuses on the connections between the new and previous knowledge (Mayer, 2001, 2005). This process includes activating the applicable knowledge in long-term memory to be matched with new information (Mayer, 2005).

These three processes for active learning are involved in instructional design theories and models. The following paragraphs include a discussion of the instructional design strategies and techniques, including the process of active learning, on how to decrease cognitive load learning.

Through the previous discussion of the three assumptions, it can be said that Dual-Coding Theory can be integrated into the first assumption while Baddeley’s (1986) model can be incorporated into the second assumption of CTML. These two theories help instructional designers to comprehend the shape and function of WM and recognize the limitations of WM in the learning process. Therefore, the limitations of WM require instructional designers to make appropriate decisions when designing multimedia instruction. The following paragraphs discuss some of instructional design strategies followed by multimedia principles that may help to reduce the cognitive load and increase the capacity of WM.

In order to come over the limitations of WM, Driscoll (2005) explains two processes that inhibit the loss of information from WM, and assist in transferring it to long-term memory. These processes are rehearsal and encoding.

Rehearsal is the repetition of information, which maintains the information in WM for a period of time (Driscoll, 2005). Rehearsal can maintain information in WM and improve recall; however, in the absence of rehearsal, information may decay with the passage of time (Schunk, 2012).

Encoding refers to the process of connecting the new information to the known knowledge and skills that are stored in long-term memory (Driscoll, 2005). Encoding strategy is a significant task that should be recognized by the teachers as well as instructional designers when designing a multimedia instruction for learners. Active learning processes that discussed earlier are supported by applying encoding strategies. Schunk (2012) stated that there are three factors influencing encoding: organization, elaboration, and schema structures.

Organization refers to the structured instruction where a significant planned material will be easier to learn and recall (Schunk, 2012). There are some effective ways that can be used to organize materials, such as hierarchies, concept maps, and mnemonics (Driscoll, 2005). These ways contribute to facilitate the learning process, assist learners to recall information, and improve memory because concepts are linked to each other in a systematic way (Schunk, 2012). This factor, organization, was considered by Allan (2003) among the six navigation principles for online design. The second principle of the navigation refers to allowing learners to see how the contents are organized in the instruction. In online courses, content organization should be very clear for learners and provide an easy access to content. Allan (2003) stated that excellent design may provide various views, such as "sequence of topics in the order of recommended study, structure listing of topics by discipline, list of topics by instructional activities provided, and list of topics by media" (p. 234). In addition, the Kemp model (1985) provides in depth different strategies, as discussed in chapter III, on how to design content in an effective organization.

The second factor is elaboration, which "is the process of expanding upon new information by adding to it or linking it to what one knows" (Schunk, 2012, p .188). This indicates that new information will be incorporated into the learning process, and is connected to the previous knowledge and skills of the learner, as well as builds upon information that has already been learned. This technique is supported by the third event of Gagne's (1985) nine events of instruction that is stimulating recall of prior knowledge, which is the retrieval of information to WM (Driscoll, 2005). By this strategy, the learner is encouraged to recall previous knowledge and skills, and integrate them with the new information to make it meaningful.

Finally, the third factor is the concept of schemas that indicates a plan or structure, which organizes a large amount of knowledge into a meaningful system (Schunk, 2012). As was previously discussed, schemas were a consideration in the instructional design field. In the principles of designing multimedia instructions, as discussed later in this chapter, Clark and Mayer (2011) indicate that a large concept should be broken into smaller segments. The capacity of WM can be functionally increased by creating larger bits, a process referred to as the process of chunking (Miller, 1956). This process allows WM to develop information effectively before it is stored in long-term memory.

Furthermore, the strategies on how to maintain learners' attention to promote an active learning, the first stage of the ARCS model are gaining and sustaining attention, which refer to acquiring and maintaining learners' attention to the instructional content (Keller, 1987). It is truly a significant task to gain learners' attention at the beginning of the lesson and sustain it through the learning processes. Allen (2003) also provides a key for motivation to maintain learners' attentions, which indicates that learners might be at risk, because if learners have something to lose they pay attention. This risk, for example, can be clear through the instructor's guidelines and instructions for each activity. By gaining and sustaining learners' attention, this can ensure their success in completing the learning processes.

To maintain learners' attention in an online environment, instructional designers should provide the instruction in different modes of learning (Driscoll, 2005). Using different techniques to present the materials will contribute to sustaining learners' attention (ChanLin, 2009). Some of these techniques include, but are not limited to, using video clips, slide presentations, discussion forums, and group activates. Clark and Mayer (2011) stated that the multimedia principle includes both words and graphics, and they support the presentation of information in different modes, visually and auditory, which fosters the active learning process.

Multimedia principles. Beside the importance of applying the previous instructional design strategies to overcome the limitations of WM, there are different several principles of multimedia design that may reduce cognitive load when designing multimedia instructions (Clark & Mayer, 2011; Mayer, 2001; Mayer, 2005). These principles were derived from the CTML, and they intend to provide a prescription on how to design multimedia instructions. The implementation of these principles is in light of CTML, which is about how people learn from words and pictures (Mayer, 2001). These principles are discussed below in following paragraphs.

The first principle is the multimedia principle, which states that "students learn better from words and pictures than from words alone" (Mayer, 2001, p. 63). It is recommended that multimedia instruction should include words and pictures rather than words alone (Clark & Mayer, 2011). Students learn better from a multimedia instruction that consists visual and verbal information than visual or verbal alone (Mayer & Anderson, 1992; Mayer, Bove, Bryman, Mars, & Tapangco, 1996). Research stated that learning from different formats, words and pictures, better than one format (Mayer, 2001) because the use of words and pictures helps students to build a connection between the pictorial and verbal information.

The spatial contiguity principle, which is the first principle of contiguity, indicates that the printed words should be placed near the corresponding graphics in multimedia instructions (Mayer, 2001). Misaligning words and pictures on the screen, such as placing words far from the corresponding pictures, requires learners to use their limited cognitive recourses to visually search on the screen, which may cause an increase in the cognitive load (Mayer, 2001; Mayer & Moreno, 2003). To reduce the cognitive load causing by misaligning words and pictures on the screen, placing corresponding words and graphics near each other on the screen rather than isolated from each other (Mayer & Anderson, 1992; Mayer & Moreno, 2003). The spatial contiguity principle allows learners to not use their cognitive recourses to visually search on the screen, which leads to reducing the cognitive load in WM.

Another principle of contiguity is the temporal contiguity principle that deals with the coordination of spoken words and graphics in multimedia instructions (Mayer, 2001). It means that corresponding graphics and spoken words need to be presented simultaneously to construct meaningful learning (Mayer & Anderson, 1992; Moreno & Mayer, 1999). When corresponding graphics and spoken words are presented in different time, learners have to use their limited cognitive resources to search about these components to match them up, and their cognitive processing are not related to the instructional objectives (Clark & Mayer, 2011). Research indicated that people learn better when corresponding graphics and spoken words are presented at the same time rather than successively (Mayer & Anderson, 1992; Moreno & Mayer, 1999).

The modality principle, as discussed initially in this chapter, recommends to processing information by using the visual and auditory channels (Sweller et al., 1998). When multimedia instructions include words and pictures and both are presented visually, the load in the visual channel will be increased, while the audio channel is unused (Mayer, 2001; Mayer, 2005). Therefore, the modality principle indicates that words in multimedia instructions should be presented as a narration rather than on-screen text (Clark & Mayer, 2011; Mayer, 2001; Sweller et al., 1998). People learn better from multimedia instructions when words illustrating concurrent pictures are presented auditorily as speech rather than visually as on-screen text (Mayer, 2001; Mayer & Moreno,1998; Moreno & Mayer, 1999). Research stated that using both visual and auditory channels may increase the capacity of WM by activating each channel of WM rather than just one (Moreno & Mayer, 1999).

The redundancy principle highly recommends that multimedia instruction should not include redundant on-screen text that is identical to the spoken words (Mayer, 2001). Mayer, Heiser, and Lonn (2001) found that adding on-screen text duplicating the same words in narration could affect students learning because on-screen text can overload the visual channel and require students to split their visual attention between two sources of information (printed words and graphics). Based on the limited capacity of WM, discussed previously, “it can be better to present less material (graphics with corresponding narration) than more material (graphics with corresponding narration and printed text)” (Clark & Mayer, 2011, p. 141).

The coherence principle indicates to exclude extraneous information in the multimedia instruction (Mayer, 2001). Extraneous information includes unnecessary material in the form of sounds, pictures, and words that are not related to the instructional objectives. Adding extraneous information to multimedia instructions may exceed the load in WM, and then it can affect learning processes. Moreno and Mayer (2000) found that adding background music or sounds to multimedia instructions could affect students learning and overload the capacity of WM as predicted by CTML. Mayer et al. (2001) also stated that adding irrelevant video clips to multimedia instructions may hurt student performance. Extraneous words and graphics added for interest can detriment learning by disrupting students from the important materials, and then results in less understanding (Clark & Mayer, 2011).

The personalization principle is to use conversational rather than formal style when presenting information to learners (Clark & Mayer, 2011). The use of personalization principle primes a sense of social presence in the learners, and they may learn better from multimedia instructions when words are said in conversational rather than formal style (Moreno & Mayer, 2004). Presenting information in conversational style makes learners feel the social presence (as having a conversation with the author), and then engage in active cognitive processing to understand what the conversational partner is saying to them (Clark & Mayer, 2011).

The segmenting principle is to break a continuous lesson into smaller parts, and each part is presented independently (Clark & Mayer, 2011). The concept of schema was discussed earlier in this chapter (Sweller, 1994; Sweller et al., 1998) and it is considered as one of the multimedia principles that should be applied when designing a multimedia instruction. The rationale of the segmenting principle is when breaking the multimedia instruction into manageable segments, it helps learners to process a small amount of information at one time without overloading the cognitive processes (Clark & Mayer, 2011; Sweller et al., 1998). Researchers have provided evidence indicating that learners who study and apply the segmented parts in a complex task perform better than learners who study the continuous whole (Clark & Mayer, 2011; Mayer & Chandler, 2001).

The pretraining principle recommends that learners should know the names and characteristics of the main concepts in the multimedia instruction (Clark & Mayer, 2011). In a complex lesson, learners need to know the terms and their characteristics as well as the interaction among them to understand the lesson. However, learners who are familiar with concepts of materials may not need pretraining; therefore "pretraining can help beginners to manage their processing of complex material by reducing the amount of essential processing they do at the time of presentation" (Clark & Mayer, 2011, p. 215). Providing a pretraining in the names of trams and characteristics of the concepts before studying the complex lesson can help learners to obtain a meaningful learning (Mayer, Mathias, & Wetzell, 2002).

Multimedia principals provide different strategies on how to design the multimedia instruction that does not overdo the cognitive load. Since WM can be divided into two channels, auditory and visual (Seufert, Schutze, & Brunken, 2009), the instructional designer is encouraged to use both channels, rather than a single one to functionally increase the capacity of information procession (Clark & Mayer, 2011). The load on the visual channel can be reduced by shifting some of the load to the auditory channel by presenting verbal informative as speech, which explains the modality principle. This indicates that both audio and visual channels can play an important role in reducing cognitive load and communicating information to learners. Therefore, the modality principle was investigated in this study.

Generally speaking, the limitations of WM were recognized by Mayer's (2005) CTML, which was based on previous theories, such as Dual-Coding Theory and Baddeley's (1986) model. Therefore, instructional designers should be aware of WM characteristics and its function through the process of designing instruction. CTML provides a framework on how to design effective multimedia instructions. Overall, CTML helps to understand the concept of the modality principle and how it can be applied in the instructional design processes to reduce the cognitive load. The following section examines the effect of modality on learning.

The Effect of Modality on Learning.

In the area of instructional design, WM has significance in the learning process and is integrated into various instructional design models. Clark and Mayer (2011) recognized the limitations of WM in their multimedia principles theory. They indicated that the modality principle of multimedia can be applied by the instructional designer to avoid the cognitive load. The modality principle can be applied by using both channels of WM, auditory and visual, to increase the capacity of WM. Therefore, the effectiveness of applying the modality principle in multimedia learning should be identified. Several studies have been conducted to examine the influence of the modality principle on learning.

Along these lines, Harskamp, Mayer, and Suhre, (2007) conducted a study to investigate the application of the modality principle in an authentic K-12 learning environment: school students learning within science classrooms. Two experiments were conducted in this study (27 and 55 students). The outcomes of this study indicated that students who received lessons containing illustrations and narration performed better on subsequent transfer tests than those who received lessons containing illustrations and on-screen text. These results referred to the modality effect can be obtained in authentic school classrooms. The researchers encouraged instructional designers to replace the printed words with spoken words in the multimedia lessons to promote meaningful learning and support learners to interact with the instruction at the same time.

Another study was conducted by Seufert, Schutze, and Brunken (2009) to examine whether the modality of text presentation has an impact on learning. The researchers conducted two experimental studies (34 and 78 participants). Their results showed that the modality effect was confirmed for less-skilled learners in memory strategy use, but not for highly skilled ones. It is evident that memory strategy skills and WM capacity affected multimedia learning, depending on task features and demands. Seufert et al. (2009) stated that the modality effect can be moderated by more general memory characteristics. Therefore, instructional designers should be aware of WM characteristics and function, through the process of designing instruction. In online instructional design, the results would be better when offering a combination of audio and slides, rather than text and slides, which can be explained by the modality effect on online learners (Debuse, Hede, & Lawley, 2009).

The influence of text modality with static and dynamic visualizations on learning was examined by Kühl, Scheiter, Gerjets, and Edelmann (2011). Participants in this study were 63 females and 17 males with different educational backgrounds from the University of Tuebingen, Germany. The design of this study was a 2 x 2 factorial design, and participants were randomly assigned to one of four conditions. The results showed that participants of the spoken experiment outperformed those of written experiments for the transfer test. Moreover, the dynamic visualization was superior to the static visualization for transfer test. These outcomes were similar to the results of Schmidt-Weigand, Kohnert, and Glowalla's study (2010). They had forty students (26 females and 14 males) of the Justus Liebig University Giessen who were randomly assigned to one of three experimental groups (spoken text, written text near to or written text far from accompanying animations). The results indicated that students from the spoken condition had better outcomes in retention and transfer than those in written text groups. However, there was no significant difference between near and far written text presentation in retention and transfer tests.

The role of the modality principle in real-time feedback was tested by Fiorella, Vogel-Walcutt, and Schatz (2012). An experimental approach (36 males and 24 females) was developed to compare the use of spoken- versus printed-text real-time feedback in a simulation-based training environment. The findings demonstrated the modality effect when the Spoken Group outperformed the Printed Group in the decision-making performance during training and assessment.

The previous studies showed the importance of the modality effect on learning in different contexts, and they demonstrated that its role increases the capacity of WM and reduces the extraneous cognitive load. However, several studies showed a reverse modality effect in some conditions (Crooks, Cheon, Inan, Ari, & Flores, 2012; Leahy & Sweller, 2011; Schueler, Scheiter, Gerjets, & Rummer, 2008), so it is important to understand the reason behind this reversal. These studies are discussed in the following sections.

The effects of text modality and visual cueing (high cueing vs. low cueing) on learning were examined by Crooks, Cheon, Inan, Ari, and Flores (2012). The 153 participants in this study were studying a computer-based static diagram and associated text at their own pace. They were randomly assigned to four versions of the computer-based materials formed into a 2 × 2 factorial design by crossing modality with cueing. The findings of this study showed a reverse modality effect, wherein participants studying written text outperformed those studying spoken text on tests of free recall, matching, comprehension, and spatial recall, but not mental effort. However, Tabbers, Martens, and Van Merriënboer (2001) also investigated the influence of presentation format on the effectiveness of multimedia instructions with different results. Two experiments (41 and 81 students) were conducted. The findings showed there was an effect of modality, which increased the effectiveness of multimedia instruction when students had no control over the pacing of instruction. Self-pacing may explain the reverse results of the modality effect found by Crooks et al. when students were studying at their own pace.

Therefore, Mayer (2005) highlighted that the learner-paced condition could be the main reason for the reverse modality effect. In addition, a meta-analysis was conducted by Ginns (2005) of 43 studies demonstrating the modality effect may be obtained under the system-paced condition. Ginns's meta-analysis explained a condition of the modality effect, which is system-paced instruction that should be recognized when designing a multimedia instruction.

Leahy and Sweller (2011) conducted two experiments (24 and 64 students) within a cognitive load theory framework to explore the effect of modality. The results from the first experiment showed a reverse modality effect and the researchers attributed these outcomes to the length of the auditory and visual text. However, in the second experiment, the length of auditory and visual text was reduced and the results indicated there was a modality effect with audio/visual instructions proving superior to visual only instructions. Another meta-analysis was conducted by Reinwein (2012) of 86 studies indicated that the modality effect can be observed within short texts. These findings provided clear directions for instructional designers to consider the length of instruction that can be delivered through the visual presentation.

The theoretical explanation and the boundary conditions of the modality principle were examined by Schueler, Scheiter, Gerjets, and Rummer (2008). The researchers conducted two experiments (68 and 81 students) to clarify the theoretical explanation and explore the boundary conditions of the modality effect. The researchers explained that the results are somewhat disappointing because they did not provide clear response to the research questions. The outcomes showed there was no main effect of modality. Therefore, this indicated that more research is needed to investigate the theoretical explanation and the boundary conditions of the modality effect.

The previous studies highlighted conditions critical to observing the modality effect. Sweller, Ayres, and Kalyuga (2011) summarized some conditions that should be applied when designing an instruction to obtain a modality effect. These conditions include a high level of element interactivity, limited spoken text, strong connection between audio and visual sources of information, and cuing to refer to the complex visual part. Moreover, the meta-analyses conducted by Ginns (2005) and Reinwein (2012) indicated that the modality effect may be obtained under system-paced presentation and short text.

Examination of both these meta-analyses revealed the modality principle has been applied in various subject areas. Some of these curriculum areas include Botany, Electrical Circuits, Meteorology, Geometry, Algebra, Mechanics, English, History, Instructional design, Logic, and Human Circulatory System (Ginns, 2005; Reinwein, 2012). Although mathematics is one of the subjects that can be taught by applying the modality principle, only a few studies have examined the effect of modality on mathematics (Atkinson, 2002; Jeung, Chandler, & Sweller, 1997; Mattis, 2012; Mousavi, Low, & Sweller, 1995). Thus, this literature review is narrowed down to examine these few studies in the following section.

The effect of modality on mathematics learning. Mousavi, Low and Sweller (1995) conducted four experiments with Australian high school students (30 eighth-year students in each experiment) and two experiments with Australian fourth-year students (40 fourth-year students in each experiment) to investigate the effectiveness of a modality principle-based presentation of Geometry under different conditions. Both eighth and fourth years' students in this study were equivalent to the United State eighth and fourth grades. The first four conditions included a simultaneous group, a visual-visual group and a visual-auditory group (Experiment 1), equalized presentation times for all the groups (Experiment 2), varying presentation sequences (Experiment 3), equalized study times for all the conditions (Experiment 4). The last two experiments included different instructional materials with equalized times (Experiment 5) as well as cognitive demanding of reading and listening process (Experiment 6). The results showed that there was a modality effect. This study showed a mixed auditory and visual mode of presentation was more effective than a visual mode. The results also indicated that there was no significant effect for the differences in times or presentation sequences. In addition, the findings did not show a significant difference between cognitively demanding processes of reading and listening. These outcomes of the experiments under various conditions explain that WM capacity can be increased when mixed modes of presentation are used to teach Geometry.

Moreover, another study was conducted by Jeung, Chandler, and Sweller (1997) to investigate the modality effect with year six and four students using Geometry materials. They conducted three experiments to examine the modality effect with high and low search as well as the visual indicators. High and low search is defined as the complexity of the visuals materials in the training module (Jeung et al.,1997). The modality effect was observed with high search materials and absence with low search materials. In addition, the researchers highlighted the importance of including visual indicators, such as electronic flashing, color, or animation to the audio-visual instruction to be more effective, especially with complex materials. These conditions were supported by Mayer (2005).

A different area of mathematics, Algebra, has been studied at the post-secondary level. The literature review showed that the research on the effect of modality on mathematics learning at the post-secondary level is limited to Algebra area. Also, the number of studies on Algebra is somewhat limited (Atkinson, 2002; Mattis, 2012).

Atkinson (2002) examined the auditory and visual presence of animated pedagogical agents using Algebra materials with 75 undergraduate students (22 males and 53 females). The results showed no significant difference between the voice-only group and text-only group. However, the voice-plus-agent condition was superior to both voice-only and text-only conditions. These results showed that an animated pedagogical agent can promote learning, based on Mayer's (2005) explanation discussed earlier.

Algebra material was used by Mattis (2012) to examine the effect of modality on mathematics accuracy and perceived mental effort at different levels of complexity with 48 undergraduate nursing students. The results showed the modality effect was not obtained on accuracy or perceived mental effort. It is noted that 83% of the students who participated in this study were female, and the results indicated female learners felt more confident when studying through visual instruction.

Gender and Mathematics Learning

In order to understand the historical context of gender differences in mathematics learning, it is an appropriate to examine some the previous studies. Gender differences in mathematics learning had been investigated in research since at least the early 1970s. Fennema (1974) identified a gender gap in mathematics performance, favoring males. Benbow and Stanley (1980) found male students in high school performed better than female students in a mathematical test of the Scholastic Aptitude Test. Valentine (1998) stated that the gap of gender in mathematics achievement seems to be reduced, but it still exists. In addition, the moderating role of mindful learning for gender differences was examined by Anglin, Pirson and Langer (2008). The results showed that gender differences in mathematics performance on a novel math task were obtained, favoring males, when the instruction does not support mindful learning. However, these results indicated both genders performances are equally well when instruction encourages mindful learning, which plays an important role in gender performance.

The results of a meta-analysis, which was conducted to examine gender differences in mathematics learning in 242 studies, reported that there is no longer gender difference in mathematics learning, especially in elementary and middle school (Lindberg, Hyde, Petersen, & Linn, 2010). These results also showed a slight effect for high-school and college students favoring males, but in overall, Lindberg et al. (2010) stated that gender differences in mathematics learning are small.

Moreover, the National Assessment of Educational Progress (NAEP) in 2015 evaluated fourth and eighth students' performances in mathematics and reading (NAEP, 2015). For mathematics evaluation, students average score was 240 points at fourth grade and 282 points at eighth grade on separate 0-500 point scales. This report indicated that the average score of male students (241) was higher than female students (239) by two points on mathematics performance at fourth grade. However, the average scores of male and female students at eighth grade were equal with both genders average having an average scale score of 282 (NAEP, 2015). Thus, the results of NAEP report clarified that the difference on gender performance was limited.

By examining this latest report of the NAEP 2015, it can be seen that a proportion of female and male students were able to achieve proficient level. In this latest report, achievement levels--basic, proficient and advanced--were used to report student performance, with a specific definition of each achievement level for each grade. For example, the proficient level explains a solid academic performance for each grade and it begins from 249 points for fourth grade and 299 points for eighth grade on separate 0-500 point scales.

The results showed that 42% of male students in fourth grade performed at or above the proficient level (249 points) compared to 38% of female students in fourth grade (NAEP, 2015). In eighth grade, 34% of male students performed at or above the proficient level (299 points) compared to 33% of female students (NAEP, 2015). Female students trailed male students by only four percentage points at fourth grade and one percentage point at eighth grade. Therefore, female and male students have almost equal performance on complex level of mathematics content (Geist & King, 2008). Although there is a difference between males and females in mathematics learning, this does not mean that either gender is better than the other, but the way on how to process learning may be different (Geist & King, 2008).

Male and female students have positive attitudes towards mathematics as valuable materials that are used in daily life (Amirali, 2010). However, male students may value mathematics more than females, and that may be due to their recognition of the importance of learning mathematics content that is required to work as an engineer or scientist (Samuelsson & Samuelsson, 2016). Schwery, Hulac, and Schweinle (2016) stated that although male students may get higher scores on a mathematics test, this difference is still negligible, which indicates that the effect of gender differences on mathematics performance is very small.

In addition, another possible explanation of gender differences may be that poor performance in mathematics learning may relate to mathematics anxiety (Ma & Xu, 2004). These authors went on to state that female students may have higher level of mathematics anxiety than males. Mathematics anxiety is defined as an uncomfortable state that students feel when they want to perform a mathematical task (Ma & Xu, 2004). The relation between mathematics anxiety and performance was examined by Devine, Fawcett, Szűcs, and Dowker (2012). Their results showed that there is a negative correlation between mathematics anxiety and mathematics performance for female and male students, which explained that students with high mathematics anxiety achieved a lower level of mathematics performance (Devine et al., 2012). The results also indicated the level of mathematics anxiety with female students was higher than males; however, there was no gender difference in mathematics performance (Devine et al., 2012). Since the study of Devine et al. showed no gender difference in mathematics performance, female students may perform better than male, but their mathematics anxiety could affect their performance.

Teachers' attitudes of mathematics could affect students' performance in mathematics. Research found that female mathematics teachers who have mathematics anxiety pass on to female students the stereotype that male students perform better than female students at mathematics performance (University of Chicago, 2010). Female students at elementary school who endorsed this stereotype performed at a lower level than males in mathematics (University of Chicago, 2010). Students at elementary school are higher influenced by their teacher's attitudes, and this impact could continue to affect student's mathematics performance throughout upcoming years. Ma and Xu (2004) stated that poor mathematics performance in the past can lead to higher mathematics anxiety in high school students. Since the teachers' anxiety about mathematics might reduce female students' mathematics performances, these issues of anxiety and mathematical attitudes need to be addressed in future teachers by more mathematical preparation (University of Chicago, 2010).

Moreover, some of the differences between gender in mathematics performance have been linked to the way males and females learn (Geist & King, 2008). With this point in mind, classroom atmosphere, learning style, and instructional activities and experiences designed for males and females learning may not be enough to meet the needs of either gender (Geist & King, 2008). For example, in the classroom setting, male students may be more active and tend to work in groups more than females, who may prefer to focus on their own work (Samuelsson & Samuelsson, 2016). Teachers should foster the self-efficacy of all students by designing appropriate activities including mastery experiences on mathematics content, frequent opportunity for practice, and sufficient feedback (Schwery et al., 2016).

Overall, most results of the previous research highlighted that gender differences in mathematics are small and recommended that instructional activities take into account the needs of both genders. Although the types of studies and conclusions have changed over time, the topic remains of interest. Therefore, it is appropriate to examine the gender with multimedia instruction, especially the modality principle.

Gender and the Modality Principle

The effects of gender and modality on learning from a computer was examined by Flores, Coward, and Crooks (2010). They identified that males may learn better from a dual mode presentation, whereas females may prefer to study through the single mode of presentation if the goal is to transfer information to new contexts. This study provided results regarding the influence of gender, which has become an important factor in the multimedia learning. Therefore, this factor should be recognized by instructional designers, in order to provide an effective multimedia learning environment. Mattis (2012) recommended examining gender and learning preferences with multimedia instructional formats. Thus, the current study investigated the effects of modality across gender when teaching a concept of mathematics.

Summary

This literature review shows there were few studies conducted to explore the modality effect on learning mathematics contents. Also, the participants in most of these studies were from grade 4-6. Therefore, the gap identified by this literature review indicated there was a lack of research investigating the effects of modality across gender on learning Algebra, especially with higher education students.

Therefore, this study aimed to examine the effects of modality across gender on learning mathematics contents for undergraduate students. The gap in the literature reviewed showed the need for this study, especially in mathematics and with university students. The results of this study may provide guidance not only for the mathematics instructors but also for instructional designers.

CHAPTER III

Methods

The purpose of this study was to test the effects of modality across gender on mathematics learning when teaching the "Introduction to Functions and Function Notation" to undergraduate students at a medium-size university in the Intermountain West. Thus, the research method of this study was the quantitative method by applying the randomized block design. The study included two different types of treatments: graphics and written text (GT), and graphics and narration (GN). The research questions were developed based on the purpose of this study as shown in the next section.

Research Design and Questions

As discussed in Chapter I, this study included two different independent variables: the modality principle and gender. Each variable had two different levels. The randomized block design was used, where participants were blocked by gender. Participants were blocked by gender because gender cannot be randomly assigned. Within blocks (M – F), participants were randomly assigned into two different treatments (GT – GN). A 2x2 factorial ANOVA design was used to assess the effects of two types of instruction across gender on student achievement.

In order to address this area of concern and based on the prior research, the guiding questions for this study are listed below. Each question is followed by the null and alternative hypotheses.

1. Do modality and gender have effects on student achievement when learning mathematics concepts?

1.1 Is there a main effect of modality on student achievement, as measured by the scores of students, who learn an "Introduction to Functions and Function Notation" through graphics and narration (GN), as compared to those who learn through graphics and written text (GT)?

The null and alternative hypotheses for the first research question state:

H_0: $\mu_{1.} = \mu_{2.}$ There is no significant mean difference in student achievement between students who learn through graphics and narration (GN), as compared to those who learn through graphics and written text (GT).

H_1: $\mu_{1.} \neq \mu_{2.}$ There is a significant mean difference in student achievement between students who learn through graphics and narration (GN), as compared to those who learn through graphics and written text (GT).

1.2 Is there a main effect of gender on student achievement between those who learn an "Introduction to Functions and Function Notation"?

The null and alternative hypotheses for the second research question state:

H_0: $\mu_{.1} = \mu_{.2}$ There is no main effect of gender on student achievement between students who learn through graphics and narration (GN), as compared to those who learn through graphics and written text (GT).

H_1: $\mu_{.1} \neq \mu_{.2}$ There is a significant mean difference of gender on student achievement between students who learn through graphics and narration (GN), as compared to those who learn through graphics and written text (GT).

1.3 Is there an interaction effect on student achievement due to the combination of modality (GT – GN) and gender (M – F)?

The null and alternative hypotheses for the third research question state:

H_0: $\mu_{11} = \mu_{12} = \mu_{21} = \mu_{22}$ There is no interaction effect on student achievement due to the combination of modality and gender.

H_1: $\mu_n \neq \mu_m$ There is an interaction effect on student achievement due to the combination of modality and gender.

As explained above, these research questions were evaluated using a 2x2 factorial ANOVA design. The answers to these research questions could add to the research literature relative to the applicability of the modality principle to mathematics learning environments and gender differences as well.

Participants and Sampling

The population of this study included students from a medium-size university in the Intermountain West. The accessible population was all students who were enrolled in the Intermediate Algebra course (MATH 1108). Students from the Elementary Algebra course (MATH 0025) were added during the experiment to get more participants. There were 1071 students enrolled in MATH 1108 and 187 students in MATH 0025 for Fall 2017. Participants were recruited from these two courses.

The desired number of participants in this study was approximately 128 students. However, this study was conducted with 108 students who were enrolled in these courses. There was a desire to get an equal number of gender in this study to examine the effect of gender. However, there were 74 females and 34 male students who had participated in this study. Participants were invited to participate in this study as volunteers. Their consents were collected prior to conducting the study.

As will be discussed in depth later in this chapter, students who usually register for these classes have similar levels of prior experiences about the contents of functions and function notations. Algebra courses were general educational courses at the institution. Regardless of academic majors, students are required to take these courses if they did not pass the campus test. Therefore, teaching a concept of Algebra for those students would be high search category and the modality principle would be expected to have an effect.

Because participants were in Algebra courses, it was assumed that they had the necessary math skills to potentially succeed in their mathematics courses. Further, it was assumed that any exposure to functions and function notation would have only occurred in a secondary-level mathematics course. This was confirmed by the course instructors who stated functions were not a topic of the MATH 0025 course and had not yet been taught in MATH 1108.

Since they were enrolled in a college course, it was also assumed that they have the necessary skills for an academic university, including college levels of reading, writing, computer skills and Internet skills. Some of the targeted learners came from different states or countries. So, they may have various educational backgrounds, but all speak English and study the same materials. Participants gave consent to participate in the study, completed the assigned module, and took the same posttest.

Since the 2x2 factorial ANOVA design was used in this study, participants were first blocked as female or male in the gender factor. Within these blocks, the participants were randomly assigned into different types of instructions [graphics and narration (GN), and graphics and written text (GT)]. The goal was to have equal sample sizes, but in fact, sample sizes within groups were unequal.

Materials

The concept of mathematics that was taught in this study was the "Introduction to Functions and Function Notation" for undergraduate students at the institution. This experiment was delivered completely through the institution's learning management system (Moodle) as an online course. Since the purpose of this study was to test the effectiveness of applying the modality principle, this study included two different treatments (the instructional intervention phase): (a) graphics and narration (GN) and (b) graphics and written text (GT). For the GT group, both statement and graphic items were simultaneously displayed on the computer screen. Figure 2 shows what computer screen used in this study looks like in this condition.

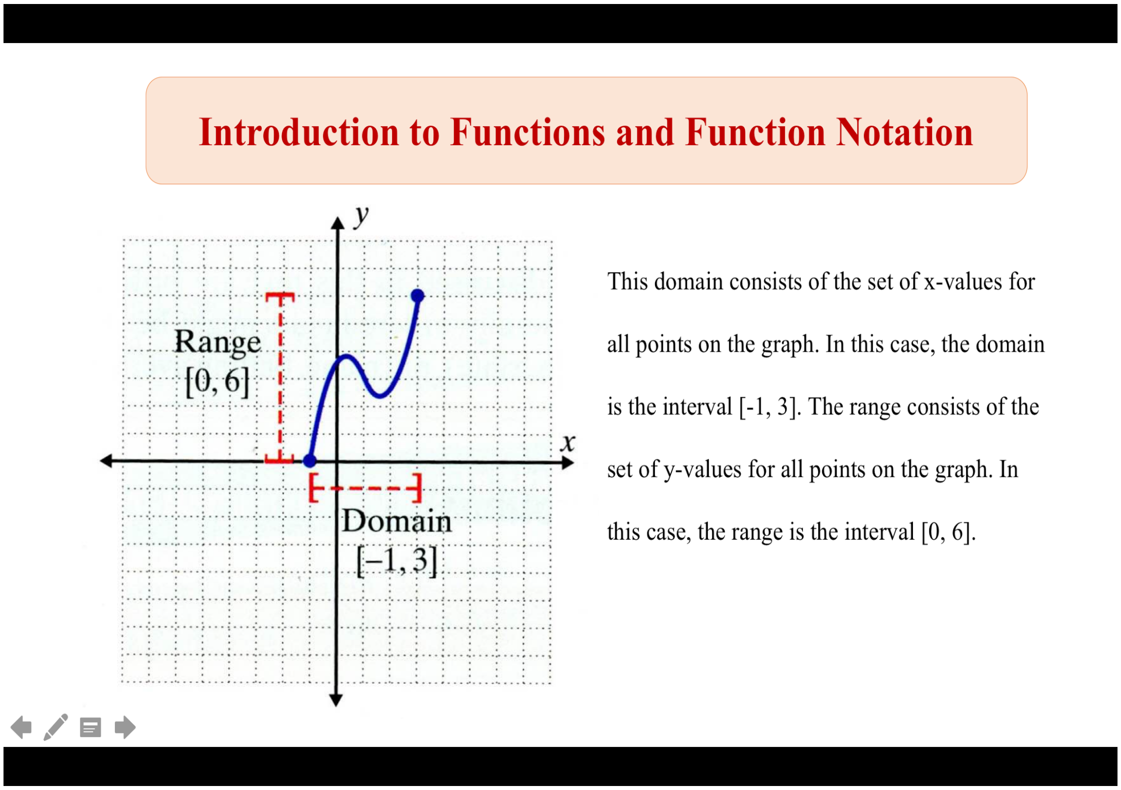


Figure 2. Example of the presentation slides of the graphic and written text instruction.

In contrast, the graphic item was presented on the computer screen for the GN, and the statement was presented as a narration. Figure 3 shows what the computer screen with narration looks like, which was used in this study. It provided text with audio based on the concept of the modality principle to help participants understanding the mathematics problem that appears on the screen. Visual indicators such as color were included in both treatments to get the students' attention to the complex part (Sweller, Ayres, & Kalyuga, 2011). Participants had no control on the presentation in light of Ginns (2005) and Reinwein's (2012) recommendations, which indicated that presentations should be system-paced. Also, both treatments had included a high level of element interactivity and strong connection between spoken text/written text and graphics sources of information. In addition, the spoken text and written text were limited.

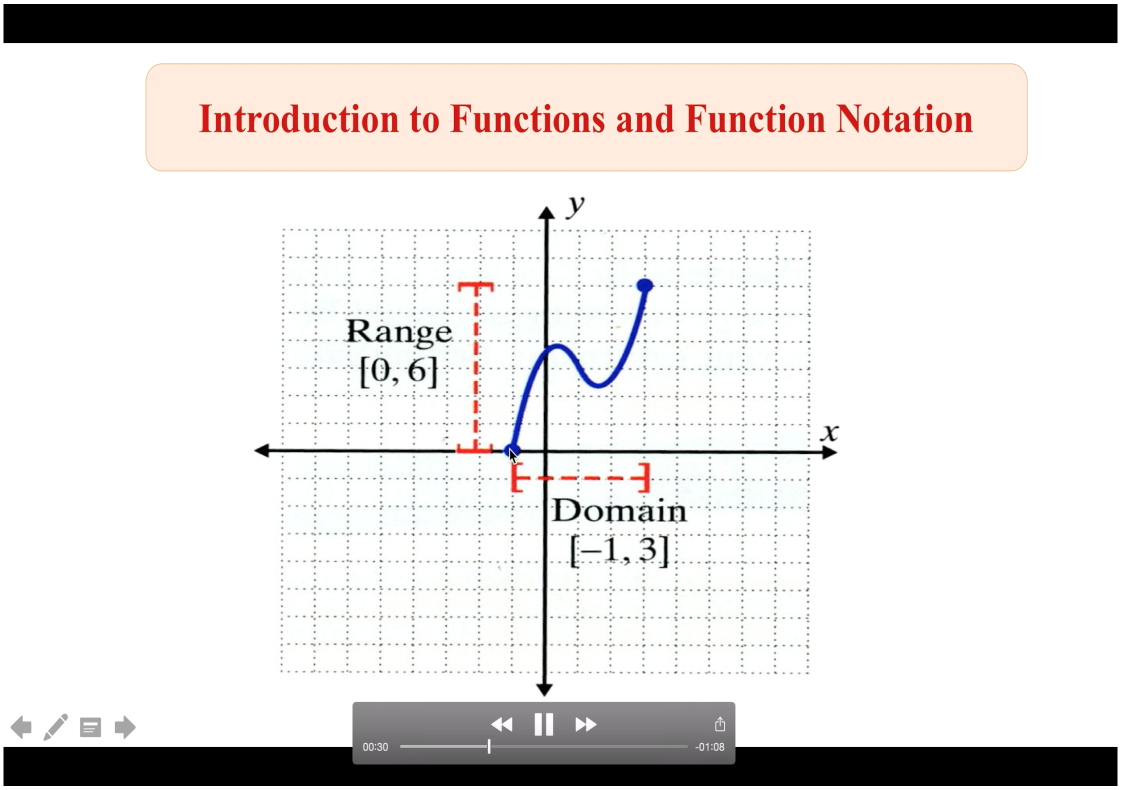
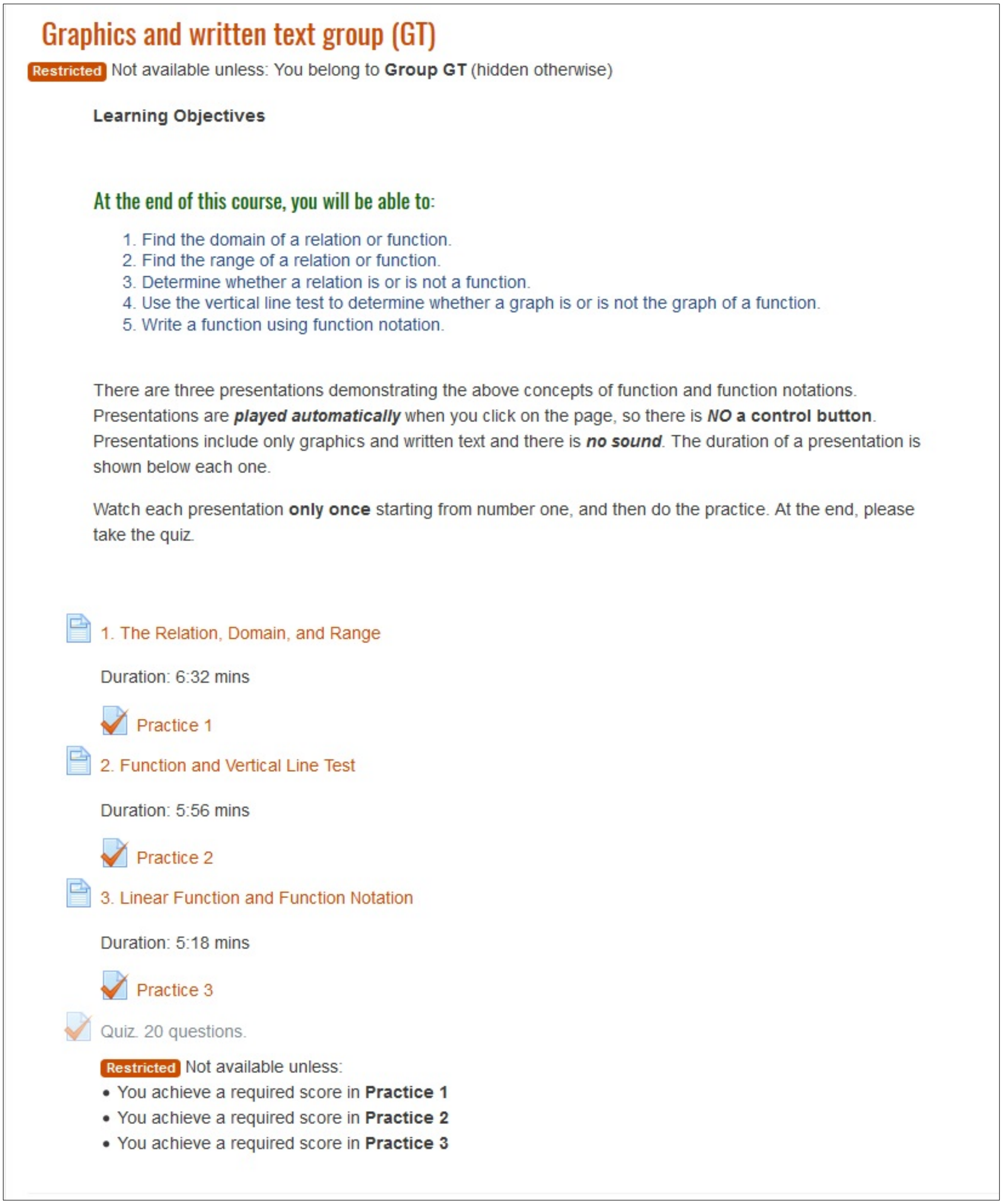


Figure 3. Example of the presentation slides of the graphic and narration instruction.

The content of the "Introduction to Functions and Function Notation" was covered through three presentations for each group. Under each treatment in the Moodle’s page, participants can see the names of the presentations and their durations. Also, the directions and information about the contents were provided on the same page of Moodle for each treatment. Figure 4 shows how the Moodle’s page of the GT treatment looks like, and Figure 5 shows also the Moodle’s page of the GN treatments. It should be noted that presentations in both treatments were identical in the contents and durations but different in the design based on the condition for each group.

It should be noted that both treatments were designed based on the multimedia principles that were discussed in Chapter II except for the modality principle, which was examined in this study. Therefore, the GT treatment did not contain the modality principle while the GN treatment was designed based on the concept of the modality principle. In other words, the modality principle was isolated in this study to be examined.



Graphics and written text group (GT)

Restricted Not available unless: You belong to **Group GT** (hidden otherwise)

Learning Objectives

At the end of this course, you will be able to:

1. Find the domain of a relation or function.
2. Find the range of a relation or function.
3. Determine whether a relation is or is not a function.
4. Use the vertical line test to determine whether a graph is or is not the graph of a function.
5. Write a function using function notation.

There are three presentations demonstrating the above concepts of function and function notations. Presentations are ***played automatically*** when you click on the page, so there is ***NO*** **a control button**. Presentations include only graphics and written text and there is ***no sound***. The duration of a presentation is shown below each one.

Watch each presentation **only once** starting from number one, and then do the practice. At the end, please take the quiz.

1. The Relation, Domain, and Range

Duration: 6:32 mins

Practice 1

2. Function and Vertical Line Test

Duration: 5:56 mins

Practice 2

3. Linear Function and Function Notation

Duration: 5:18 mins

Practice 3

Quiz. 20 questions.

Restricted Not available unless:

- You achieve a required score in **Practice 1**
- You achieve a required score in **Practice 2**
- You achieve a required score in **Practice 3**

Figure 4. The Moodle's page of the GT treatment.

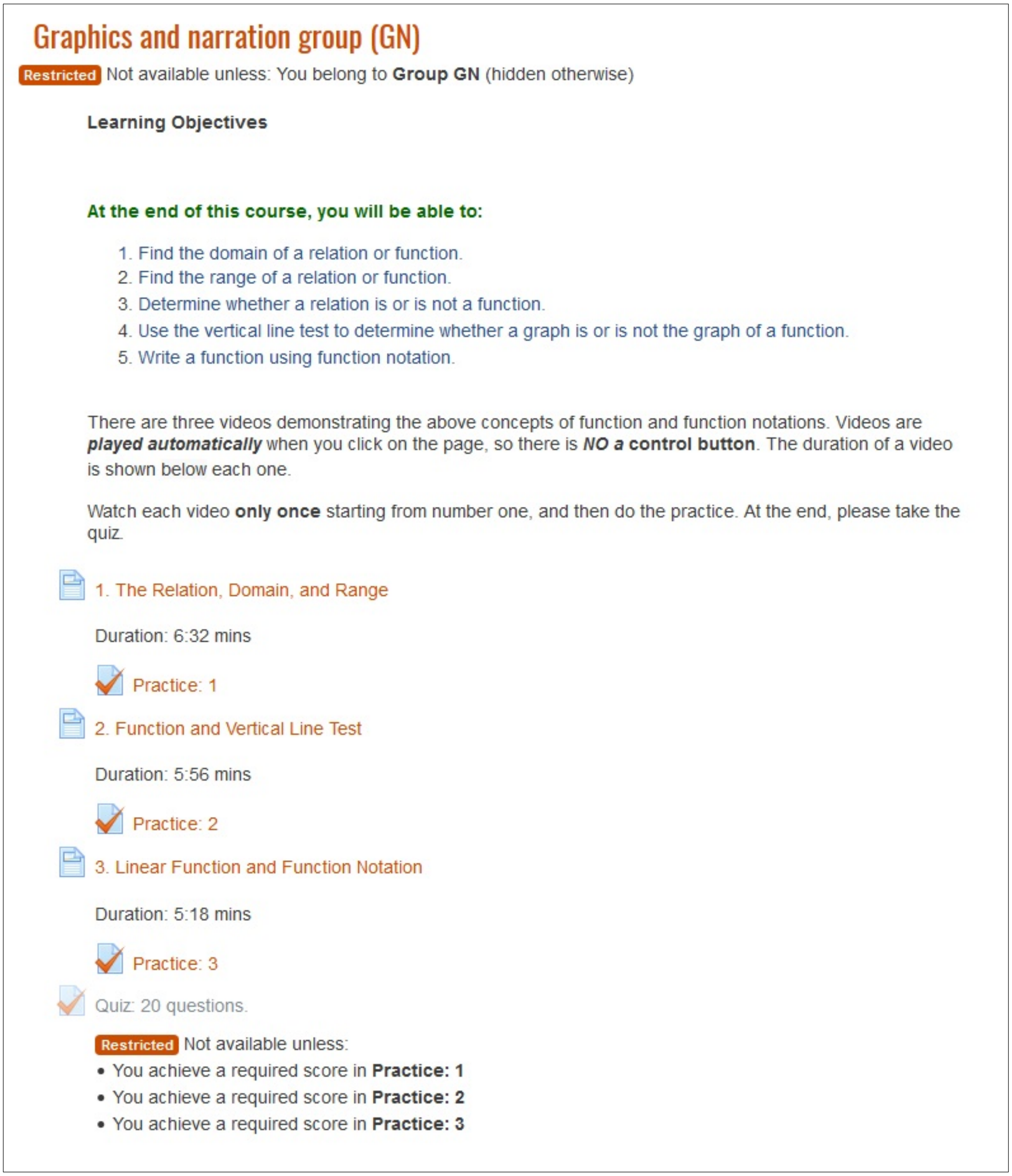


Figure 5. The Moodle's page of the GN treatment.

Each presentation was followed by one practice session, which required the participant to complete it. After the participant studying all the materials, participants had to take the posttest. The restriction on completing the posttest was the completion of the three practices. The practices and the posttest were same for both groups. All of the experimental treatments were conducted via the institute's learning management system (Moodle); the study was open for participants up to two weeks. This experiment was designed to be conducted by each participant individually.

Both treatments started running at the same time and for the same length. In the GT group, learning resources were provided through PowerPoint slides including graphics and some written text. However, in the GN group, learning resources were provided via videos accompanied with graphics and narration for clarifying some problems that might not appear via the visual items. After completing this phase, students took a posttest, which includes 20 math problems.

Instructional Design of Materials

Instructional design is defined as "the systematic and reflective process of translating principles of learning and instruction into plans for instructional materials, activities, information recourses, and evaluation" (Smith & Ragan, 2005, p. 4). There are different models of instructional design guiding the designer to create an effective instruction and supporting the learner to organize the course contents at different levels (Chen, 2008). This project was designed based on the Kemp's instructional design model. The Kemp model was developed at first time by Kemp in 1985, and then modified and revised by Kemp, Morrison, and Ross in 1994. The current version of the Kemp model is shown in Figure 6, which comprises nine elements (represented by the circles inside the Figure) and eight processes (represented by the outer ovals of the Figure) that are ongoing during the duration of the instructional design processes

(Morrison, Ross, Kalman & Kemp, 2011). The shape of this revised model is oval, which indicates this model is non-linear design and provides flexibility for designers to work in all instructional design processes as appropriate for their projects (Morrison et al., 2011).

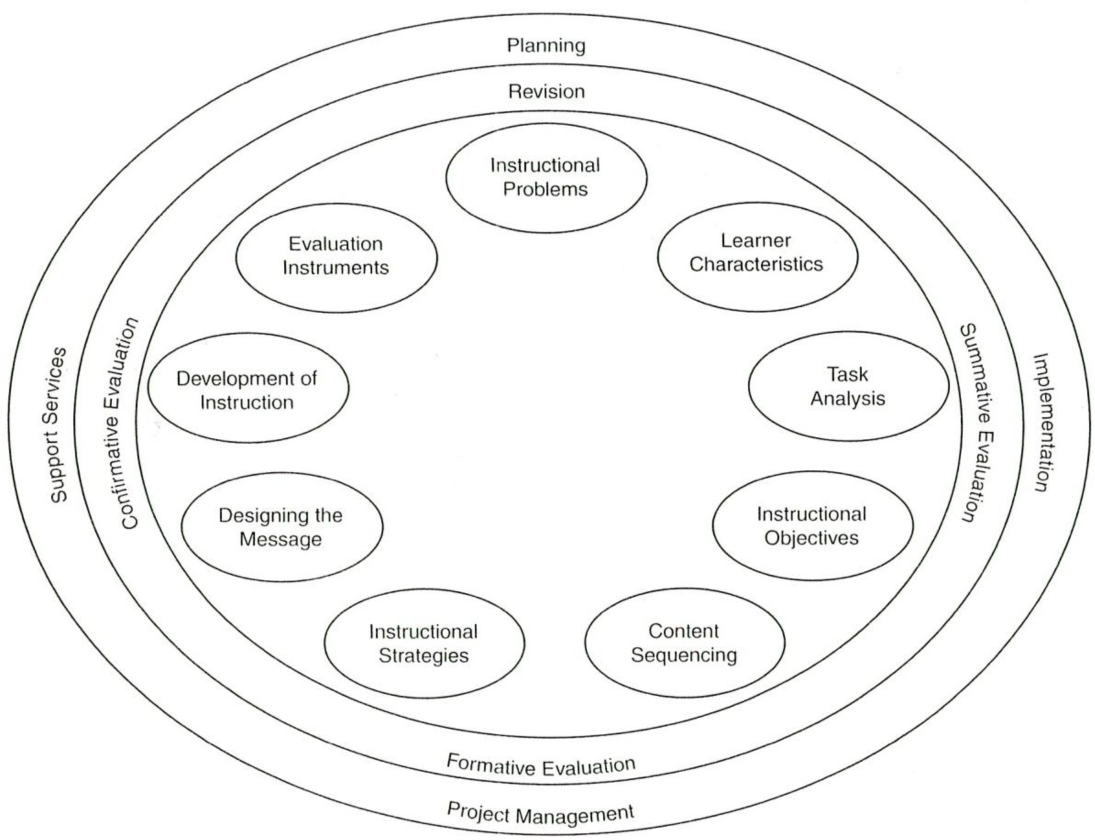


Figure 6. The Kemp model (Morrison et al., 2011, p. 12).

The following paragraphs describe the appropriate components of the Kemp model that were used to design the treatment of this study. The treatment was about an instruction of the "Introduction to Functions and Function Notation" that was designed based on the concept of modality principle for undergraduate students at the institution.

Instructional problem. Some of Algebra students at the institution were struggling with some contents of Algebra. Most of the students have difficulties to understand "Introduction to Functions and Function Notation" (R.-P. Potter, personal communication, July 22, 2016). This intervention was designed to address this need with undergraduate students who studied Algebra courses. Instructional design has an important role in the learning process. The goal of the instructional design is to make learning more efficient and effective and less difficult (Morrison et al., 2011). Therefore, this project was intended to teach undergraduate students the concept of the "Introduction to Functions and Function Notation". The goal of this project was to use the Kemp ID model to design an instruction about the "Introduction to Functions and Function Notation" based on the modality principle for undergraduate students at the institution.

Learner characteristics. This course was designed for undergraduate students who studied Intermediate Algebra course (MATH 1108) or the Elementary Algebra (MATH 0025) at the institution to teach them the "Introduction to Functions and Function Notation". Students were undergraduate and they had at least a basic college level of reading, writing, and basic computer skills, including word processing, presentations, and the use of the Internet. Some of the targeted learners came from different states or countries. So, they may have various educational backgrounds, but all speak English and study the same materials.

Theses Algebra courses included female and male students and they were enrolled in these courses. The concept of the "Introduction to Functions and Function Notation" was not from the curriculum of MATH 0025. However, students from MATH 0025 were still eligible to join this study since they did not study this concept in their class. Students from MATH 1108 did not study this concept until the end of this semester, Fall 2017. As discussed above, any experience regarding functions and function notation would have only occurred in a secondary mathematics course. Students from MATH 0025, who were placed in this remedial course by a placement test, may not have had exposure to all of the prerequisites for functions and function notation. Because of this difference in prior knowledge, it was expected the students from MATH 0025 would have lower mean achievement score than students from MATH 1108. As indicated by the instructor of this course, the "Introduction to Functions and Function Notation" is a difficult concept for most of the students. Therefore, designing this instruction by using the modality principle application may motivate students to join this course.

This course was delivered online. Some learners preferred to learn via auditory methods; thus, the designer included closed captioning for video materials, especially with the instruction designed based on the concept of the modality principle. Another instruction is a graphic and written text only. All the activities of this study were provided via Moodle, so each participant had an access to Moodle. Some learners might have a negative attitude due to their experiences with online courses, while others could have positive attitudes. Therefore, complete guidance and directions on how to study through this course were provided (see Appendix A for the complete Learner Characteristics Profile).

Contextual Analysis. The designing of this course may have facilitated learning through the online Learning Management System (Moodle). Targeted learners probably had experience with the Learning Management System. They also had an access to Moodle and computer labs from the Instructional Technology Resource Center (ITRC) at the institution. Learners' prior experiences in using technology might be different; thus, the ITRC offers support for any learner needs some help. Also, learners could communicate with the instructor via an email for any question.

This course was delivered online; therefore, the specific electronic hardware requirement for this project was a computer with high-speed connectivity to the Internet for each learner. This course included video materials, so learners need to have headphones. Also, they should have time management and organizations skills sufficient for completing coursework.

The materials of this course were provided through videos, slideshow, web pages, and threaded discussion in Moodle. The delivery plan for the targeted content's assessments was provided via a quiz tool in Moodle. The plan for learner self-directed materials was through Moodle, including the direction on what learners should do with the activities and assessments. In addition, the interactions and communication between students and their instructor of this course were online through the email.

Task analysis. Task analysis is considered as the most important component of the instructional design process (Morrison et al., 2011). Task analysis benefits the instructional designer to define the content of the instructional problem. Jonassen, Tessmer, and Hannum (1999) stated, "Task analysis for instructional design is a process of analyzing and articulating the kind of learning that you expect the learners to know how to perform" (p. 3). Task analysis helped the instructional designer to examine the learning objectives of this project and defined any sub-objectives (subtasks). In addition, the knowledge type of each subtask was classified based on the three types of knowledge: declarative, procedural, and structural as stated by Jonassen et al. (1999). Declarative

Knowledge is about factual knowledge; procedural knowledge is defined as the knowledge of how to perform a specific task; and structural knowledge is defined as the relating of one concept to another. Also, each subtask was categorized to environmental factors, domain type, importance, and difficulty.

The environmental factors included time to complete the task, environmental concerns are related to the specific task requirements, media that will assist in completing the task, physical condition, and learning environment. The domain type included cognitive, psychomotor, and affective (Morrison et al., 2011). The importance and difficulty were evaluated as low, medium, or high. The classification of the subtask was assigned by the instructional designer, then validated by the subject matter expert (see Appendix B for the complete Task Analysis).

Instructional objectives. The goal of this project was to use the Kemp ID model to design an instruction of the "Introduction to Functions and Function Notation" using the concept of the modality principle for undergraduate students. Instructional objectives provide a guidance for the instructional designer to design, identify and organize instructional activities for an effective learning, as well as offer a framework to evaluate learners' achievement (Morrison et al., 2011). This course had five instructional objectives validated by the subject expert matter. These instructional objectives as follows:

1. Find the domain of a relation or function.
2. Find the range of a relation or function.
3. Determine whether a relation is or is not a function.

4. Use the vertical line test to determine whether a graph is or is not the graph of a function.
5. Write a function using function notation.

The first three instructional objectives included facts and concept contents about the definition of domain, range and function, which they were categorized as declarative knowledge (Jonassen et al., 1999). The fourth instructional objective included structural knowledge about the use of vertical line to identify a function. The fifth instructional objective comprised procedural knowledge about using function notation to write a function.

Content sequencing. The efficient strategies of sequencing content support the instructional designers to organize the content in an appropriate scheme to help learners achieve the learning objectives. Posner and Strike (1976) proposed three sequencing schemes for presenting the instruction to learners: learning related, world related, and concept related. The learning-related scheme offers sequencing based on learner characteristics; the world related suggests sequencing based on spatial, temporal, and relationships in the content; and the concept-related scheme provides sequencing based on the relationships between concepts (Morrison et al., 2011). The contents of the "Introduction to Functions and Function Notation" instruction in this project comprised different concepts, which build upon each other. In other words, some concepts were a prerequisite for other to be learned. For example, the concept of a relation was a prerequisite to understanding the concepts of the domain and the range of a relation. The domain and range concepts were prerequisites to learning the concept of a function, and a function was required to study function notation. The contents were hierarchical (see

Appendix C for the complete the Learning Hierarchy and Appendix D for the complete Flowchart). Therefore, the concept-related sequencing was selected for sequencing the contents of this project.

Designing the message. This course was delivered through the learning management system (Moodle) at the institution. Therefore, the Web-Based Instruction (WBI) model was used to design the instruction. The conceptual framework of the WBI model for instructional strategies encompasses four main strategies: orientation to learning, instruction on the content, measurement of learning, and then the summary and close (Davidson-Shivers & Rasmussen, 2006). The orientation to learning strategy introduces learners to the unit of instruction and the second strategy, instruction on the content, presents information and provides practice and feedback. The measurement of learning strategy plans when assessment needs to be integrated to the WBI strategies and how the learners will be evaluated during the course to master the goal and learning objectives of the unit of instruction. The summary and close strategy is to remind the learners with the main content of instruction and help them to facilitate retention and transfer learning.

Davidson-Shivers and Rasmussen (2006) stated not all these strategies need to be included in each unit of the instruction; the use of these strategies is based on the project needs. Thus, this project did not need to include the final strategy, summary and close, because this project had a short unit and some of summary and close strategies were integrated with the previous strategies. Also, this course aimed to test the effects of modality across gender; it did not continue to teach the following contents of Intermediate Algebra. Following the WBI model, two modules were developed for this course (see Appendix E for the complete Storyboard).

Development of instruction. This course had two different modules: one module for the GT group and another one for the GN group. Both modules were teaching the same content but by different methods of teaching. In the module of GT group, learning resources were provided through PowerPoint slides including graphic and text. Learning cues were applied by coloring important components of the graphics in both modules, highlighting key information visually in a slideshow for the module of GT group, as well as, adding animation for the module of GN group.

In the GN group module, learning resources were provided via PowerPoint slides including only graphics with a combination of narration created by Office Mix to explain the components of the graphic. The activities of both modules encompassed practices and quizzes. These activities were provided through tools in Moodle such as quiz, Moodle's pages, and threaded discussions. At the end of this course, all participants in both modules had taken the posttest that was in Moodle.

Evaluation instruments. At the end of this course, the summative evaluation process was conducted. The goal of this evaluation was to test participants' knowledge about functions and function notation. Participants had to take the posttest to measure their knowledge and detect whether they have accomplished the learning objectives of this course. The type of the posttest was objective, such as multiple-choice and true/false questions. The learning objectives of this course were categorized as a cognitive domain knowledge; therefore, multiple-choice test is a useful-evaluation method to test the cognitive domain knowledge (Morrison et al., 2011). Also, one advantage of multiple choices items is that they can be objectively graded (McCain, 2005). In addition, the learning objectives were classified based on the Bloom's taxonomy to be measured (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956) (see Appendix E).

Instrumentation

This study had only the posttest that was recorded, analyzed, and evaluated. The posttest phase was conducted at the end of this course and it aimed to evaluate participants' performance to determine the final learning outcomes of the instruction. The posttest included 20 multiple-choice and true/false questions measuring participants' knowledge (see Appendix F for complete posttest questions). These questions were designed and created for the "Introduction to Functions and Function Notation" chapter of the Introductory and Intermediate Algebra book (Wright, 2012). These questions were related to the learning objectives of this course. The researcher was authorized by the publisher of the Introductory and Intermediate Algebra book to use the materials of the "Introduction to Functions and Function Notation" chapter (see Appendix G for the publisher's permission).

Procedure

The invitation to join the study was sent to all students in Intermediate Algebra (MATH 1108) and Elementary Algebra (MATH 0025) courses. Participants were recruited by using various methods. These methods were email, class visits, math center visits, and placing posters in university buildings (see Appendix H for a complete email message). The invitation included a link to the study in the university's learning management system (Moodle) and password to access the study. Participants joined the study themselves through the "self-enrollment" key on the Moodle.

Participants filled out a consent form, which required them to identify their gender to make the researcher able to block participants by gender (see Appendix I for the consent form). All participants' consents were electronically collected through Moodle system. After collecting participants' consents, each block was randomly assigned into two different treatments: graphics and narration (GN), and graphics and written text (GT). This study comprised the instructional intervention and the posttest. After participants were assigned into the appropriate treatment, then the experimental study was proceeding through Moodle. Both instructional conditions taught the same material about the concept of the "Introduction to Functions and Function Notation", but by different methods.

The general instruction and guidance were provided to all participants before starting the experiment by reading all the materials at the course level of Moodle. This study took place approximately two weeks to observe the changes in the dependent variable. The dependent variable, student achievement, was measured by test performance. Data were collected throughout the session of the experiment from both groups and then evaluated by the researcher. The study was designed to be completed individually. All of the experimental phases were conducted via Moodle.

Participants were entered into a drawing for gift cards. There was a gift card for each one out of three and the value of this card was equal to $10. The drawing was conducted at the end of the experiment by using Excel's RAND function to randomly choose a participant for each gift card.

Since this experiment was delivered via Moodle; therefore, all participants' names and emails were behind the university's learning management system (Moodle) protection and password. The data were paired within Moodle so that statistical comparisons can be made. However, the names were not copied from Moodle to the researcher's hard drive. As a result, no names of participants were ever connected to their score data anywhere but within the institute's learning management system (Moodle) website.

By carrying out this action, the results of this study could provide some information regarding the application of the modality principle in teaching Algebra contents to undergraduate students. In addition, information gathered could also provide more clarification about gender differences in mathematics learning.

Data Collection and Analysis

The data consisted of all participants' answers on the posttest from GT and GN groups paired with their gender. Since the experiment was delivered via Moodle; therefore, all participants' answers were electronically recorded and protected behind Moodle protection. Only the researcher who had an access to participants' scores in both groups. Also, only anonymized data were downloaded from Moodle site to be analyzed.

In order to answer the research questions, the researcher employed a factorial ANOVA test. This technique was used because this study had a 2x2 design with two independent variables, and each independent variable had two different levels. SPSS software was used to analyze the data. By examining the data collected from both groups, it was the researcher's intent to determine the effectiveness of the modality instruction on education. The results obtained from this study will be discussed in the next chapter.

CHAPTER IV

Results

The study was designed to examine the effects of modality across gender on mathematics learning. There were three research questions created based on the purpose of this study, and they are as follows:

1. Do modality and gender have effects on student achievement among undergraduate students learning mathematics concepts?

    1.1 Is there a main effect of modality on student achievement, as measured by the scores of students, who learn an "Introduction to Functions and Function Notation" through graphics and narration (GN), as compared to those who learn through graphics and written text (GT)?

    1.2 Is there a main effect of gender on student achievement between those who learn an "Introduction to Functions and Function Notation"?

    1.3 Is there an interaction effect on student achievement due to the combination of modality (GT – GN) and gender (M – F)?

These questions were assessed using a 2x2 factorial ANOVA design. This chapter will discuss the results of this study and the data analysis to provide answers to the research questions. The following sections explain the findings of the data analysis including the sample description, the ANOVA assumptions test, and a summary of the findings on each question.

The Sample Description

The sample of this study was drawn from students who were enrolled in Algebra courses at a public university in the intermountain west. These courses were Intermediate Algebra (MATH 1108) and Elementary Algebra (MATH 0025). All students in these courses were invited to participate in this study. They were recruited by email, class visits, math center visits, as well as placing posters in some buildings of the university. After participants filled out the consent form to join the study, they were blocked by gender. Participants, who joined the study as volunteers, were randomly assigned into two different groups: graphics and narration (GN), and graphics and written text (GT).

The length of the study treatment was approximately two weeks. The period of time of collecting the data was approximately two months. The total number of participants who gave consent to join the study was 125 students. However, 17 students did not complete the study, two of which retracted previously granted consent.

The final sample size was 108 students. Table 1 shows the demographic information for the sample of the study. As seen in Table 1, 68.5 % of participants in this study were female students (74 female students) and 31.5 % were male students (34 male students). By considering these two Algebra courses (MATH 1108 and MATH 0025) enrollment by gender, it was found 61% of students in MATH 1108 were female and 39% were male. Also, 67% of students in MATH 0025 were female and 33% were male. In general, the enrollment of students at this university was 57% female and 43% male. It is clear that the enrollment percentage of female students in both Algebra classes was higher than their percentage at the university. It was also noticed that the percentage of female students in the study was higher than their percentage in both Algebra classes.

Overall, the proportion of female participants in this study suggested the study attracted more female than male students.

The majority of participants were from the MATH 1108 course who made up 52.7% of participants (57 students), while 47.2% of participants were from MATH 0025 (51 students). It should be noted that the number of students registered in MATH 1108 (1071 students) was higher than those registered in MATH 0025 (187 students). However, with a large difference between enrollment numbers of these two Algebra classes, it seemed that students from MATH 0025 were more interested in joining the study compared to students from MATH 1108.

Table 1

Demographic Information for the Sample of 108 Students Included in the Study

Category	Number	Percentage
Gender		
Female	74	68.5%
Male	34	31.5%
Course		
MATH 0025	51	47.2%
MATH 1108	57	52.7%

Descriptive Statistics

The results summarized the descriptive statistics as shown in Table 2. It shows the means and variance for students' scores by gender and modality. In the graphics and written text (GT) group, male students (M = 82.65, SD = 20.85) outperformed female students (M = 80.68, SD = 17.96). However, female students (M = 80.95, SD = 19.29) did better than male students (M = 77.06, SD = 24.56) in the graphics and narration (GN) group. The variance of male students' scores in the GN group (*SD* = 24.56) was widely large.

The results of this study indicated that students learned from both treatments. Students in the GT group (*M* = 81.30, *SD* = 18.76) outperformed students in the GN group (*M* = 79.72, *SD* = 20.93) but the difference between means was small (1.58 point). Moreover, the results revealed the gender performances in general. As can be seen in Table 2, the performance of female students (*M* = 80.81, *SD* = 18.53) was higher than male students (*M* = 79.85, *SD* = 22.61) by .96 point. The variance of male students' scores in general (*SD* = 22.61) was widely large. These results explain that the gender difference in this study was less than one point, and it will be discussed in depth in Chapter V.

Male students in the GT group (*M* = 82.65, *SD* = 20.85) learned better than male students in the GN group (*M* = 77.06, *SD* = 24.56). Female students in the GN group (*M* = 80.95, *SD* = 19.29) did better than female students in the GT group (*M* = 80.68, *SD* = 17.96) but the difference between means was very small (.27 point).

Table 2

Means and Standard Deviations for Students' Scores by Gender and Modality

Group		*n*	*M*	*SD*
Graphics and written text (GT)				
	Female	37	80.68	17.96
	Male	17	82.65	20.85
	Total	54	81.30	18.76
Graphics and narration (GN)				
	Female	37	80.95	19.29
	Male	17	77.06	24.56
	Total	54	79.72	20.93
Total				
	Female	74	80.81	18.53
	Male	34	79.85	22.61
	Total	108	80.51	19.80

Results for Research Questions

The data from this study include participants' scores on the posttest. The posttest had 20 multiple-choice and true/false questions with a scale from 0 to 100 points. The posttest was only the measures collected and analyzed to answer the research questions. Based on the design of this study, a factorial ANOVA was run to analyze the data using SPSS software. The results are discussed below in the following sections including ANOVA assumptions.

ANOVA assumptions. An Analysis of Variance (ANOVA) has assumptions that should be checked by the researcher (Myers, Well, & Lorch, 2010). These assumptions include the independence, homogeneity of variance, and normality.

The first assumption is independence that means each participant performs the treatment independently. To help ensure the independence assumption, this study was delivered online and students asynchronously participated through Moodle. There was no interaction among students in the treatments activities through Moodle during the time of the study. Thus, this study was designed based on the principle that each participant studied the materials individually and independently from each other. Also, there was no pressure on students to join and complete the treatment. Since the study did not affect student grades, an additional source of pressure to violate independence was removed. In addition, participants' scores within each group were not influenced by other participants in the group.

The second assumption is the homogeneity of variance, which states that the group variances about are equal. This assumption was investigated in this study by applying the Brown-Forsythe procedure. The results of the Brown-Forsythe test explained that the homogeneity assumption was met, F (3, 104) = .53, p = .66. The Brown-Forsythe procedure test is the best and most frequently recommended test for measuring the homogeneity assumption (Keppel, 1991). This test can be used also when the group sizes (n_j) are unequal, and it is robust to non-normality (Keppel, 1991).

Finally, the normality assumption that indicates scores on the dependent variable are normally distributed in the population. This assumption was checked in this study by applying the Shapiro-Wilk test and illustrated that participants' scores did not meet the assumption of normality, W = .87, p = .00. The value of Kurtosis in this study is equal to .146 and its standard error is .46. The value of the skewness in this study is equal to -.98 and its standard error is .233. These results indicated the participants' scores have a negatively skewed distribution (see Figure 7). In this study, the value of skewness may be more than three times its standard error, which indicates that asymmetry might be present in the population of students (Myers et al., 2010). However, the sample size (n)

is large; therefore, the ANOVA test is considered to be robust with respect to moderate violations of this assumption (Blanca, Alarcón, Arnau, Bono, & Bendayan, 2017; Myers et al., 2010). Based on Figure 7, suggested that there was number of students whose scores trailed those of the majority of the study. Therefore, this indication may be true of the population of students in MATH 1108 and MATH 0025.

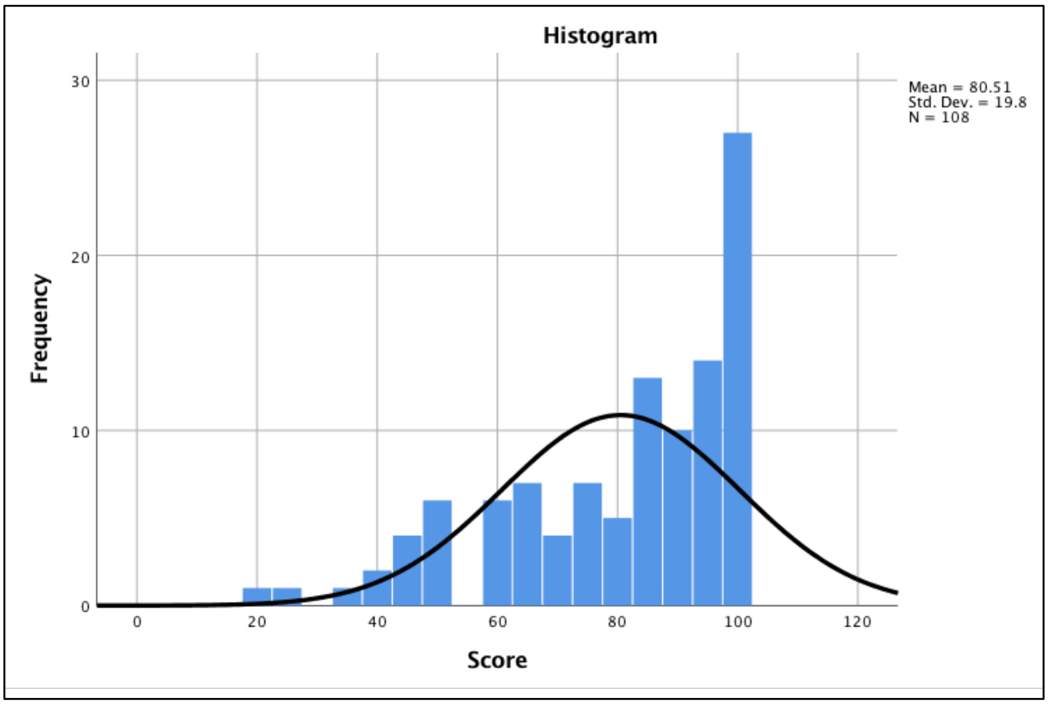


Figure 7. Students' scores distribution.

Research question 1. The first research question asked if there was a main effect of modality on student achievement. The results of two-way ANOVA, as can be seen in Table 3, showed that there was no statistically significant main effect for modality, $F(1, 104) = .41$, $MSE = 400.57$, $p = .52$, $\eta^2 = .004$. The results failed to reject the null hypothesis. These results indicated that both treatments (graphics and narration (GN) and graphics and written text (GT)) had no difference in student achievement. This outcome does not support the hypothesis that GN group would be better than GT group.

Table 3

Two-Way ANOVA for Students' Scores

Dependent Variable: Students' Scores						
Source	***SS***	***df***	***MS***	***F***	***p***	**Partial η^2**
Intercept	601343.597	1	601343.597	1501.236	.000	.935
Gender	21.375	1	21.375	.053	.818	.001
Treatments	164.709	1	164.709	.411	.523	.004
Gender*Treatments	199.894	1	199.894	.499	.482	.005
Error	41658.824	104	400.566			
Total	741975.000	108				

Research question 2. The second research question asked if there was a main effect of gender on student achievement. The results of two-way ANOVA, as shown in Table 3, indicated that there was no statistically significant main effect for gender $F(1, 104) = .05$, $MSE = 400.57$, $p = .82$, $\eta^2 = .001$. These results explained that gender did not have an effect on student achievement. Thus, this study failed to reject the null hypothesis. This finding does not support the conclusion that any gender difference exists in mathematics achievement in this context.

Research question 3. The third question was asked whether there was an interaction effect on student achievement due to the combination of modality and gender. The results of two-way ANOVA in Table 3 revealed no statistically significant interaction effect between modality and gender $F(1, 104) = .50$, $MSE = 400.57$, $p = .48$, $\eta^2 = .005$. These results failed to reject the null hypothesis that refuses the interaction between modality and gender. Although there was no statistically significant interaction effect between modality and gender, female and male students were performing differently as shown in Figure 8.

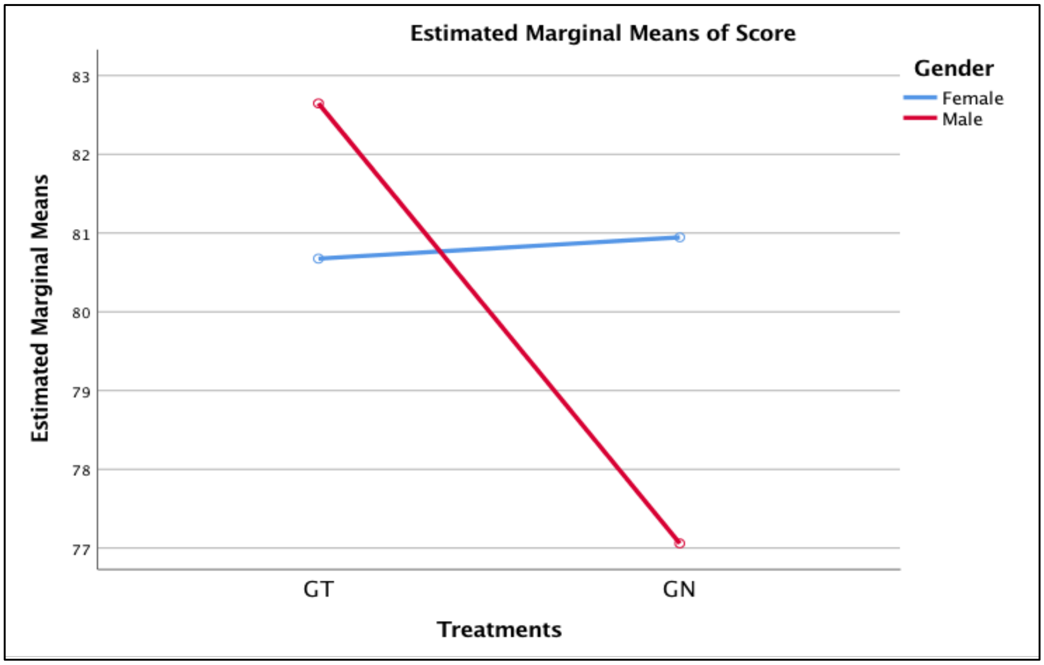


Figure 8. Interaction between modality and gender.

Additional Statistical Analysis

The number of the MATH 1108 participants (57 students) was not enough for the study. In order to get enough participants, students from MATH 0025 were invited to join the study. The materials of MATH 0025 were lower than the materials of MATH 1108, so the curriculum of MATH 0025 did not cover the concept of functions and function notation. Therefore, students from MATH 0025 were eligible to participate in this study. A factorial ANOVA was run for the whole participants in this study (N = 108), as discussed above, but the results showed no significant main or interaction effect for modality or gender. Since this study included two levels of courses and they may not have a similar population, it was considered appropriate to analyze the data separately based on the level of the course.

The statistics were run for the data of MATH 1108 and MATH 0025 independently. Table 4 provides demographic information for participants from MATH 0025 and MATH 1108 separately. As seen in Table 4, there were 57 participants from MATH 1108 course and 51 participants form MATH 0025. Female participants outnumbered males in both course samples. Although the sample size of each course was small, which reduced the power, separate ANOVAs were run for participants in each class (0025 and 1108) to see if differences between classes obscured differences by gender or treatment types. The statistical test results of each sample are discussed in the next paragraphs.

Table 4

Demographic Information for the Two Samples from MATH 0025 and MATH 1108 Students separately

	Graphics and written text (GT)	**Graphics and narration (GN)**	**Total**	
Category	Number	Number	Number	Percentage
MATH 0025				
Female	19	18	37	72.5%
Male	6	8	14	27.5%
Total	25	26	51	100%
MATH 1108				
Female	18	19	37	64.9%
Male	11	9	20	35.1%
Total	29	28	57	100%

The three ANOVA assumptions for the sample from MATH 1108 were assessed. The results of the Brown-Forsythe test revealed that the homogeneity assumption was met, F (3, 53) = .74, p = .56. The normality assumption for this sample was checked by applying the Shapiro-Wilk test and showed that participants' scores did not meet the assumption of normality, W = .78, p = .00 (see Figure 9). A transformation of data was applied by using the logarithmic transformation to address this violation. However, the results of transformed data were not different than original data. Furthermore, it has been stated that the violations of normality do not invalidate the results (Montgomery, 1991; Ramsey & Schafer, 2002). The sample from MATH 1108 was a part of the whole study, so it had all the procedures that were applied to ensure the independence assumption as discussed above.

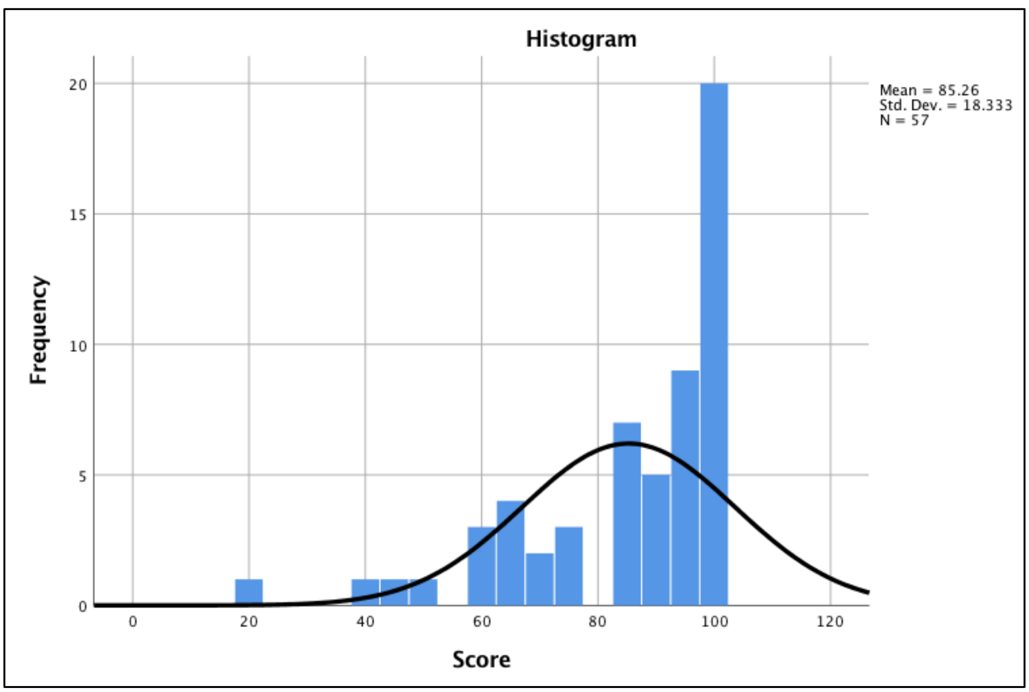


Figure 9. Students' scores distribution in the sample from MATH 1108.

A two-way ANOVA was conducted to answer research questions for the sample from MATH 1108. The results of the ANOVA test showed that there was no statistically significant main effect for modality, F(1, 53) = 2.34, MSE = 328.66, p = .13, η^2 =.042, or gender $F(1, 53) = .96$, $MSE = 328.66$, $p = .33$, $\eta^2 = .018$ (see Table 5). The results also revealed there was no statistically significant interaction effect between modality and gender $F(1, 53) = .15$, $MSE = 328.66$, $p = .71$, $\eta^2 = .003$.

Table 5

Two-Way ANOVA for Students' Scores of MATH 1108

Dependent Variable: Students' Scores						
Source	***SS***	***df***	***MS***	***F***	***p***	**Partial η^2**
Intercept	381333.593	1	381333.593	1160.275	.000	.956
Gender	319.055	1	319.055	.962	.331	.018
Treatments	770.211	1	770.211	2.344	.132	.042
Gender*Treatments	47.560	1	47.560	.145	.705	.003
Error	17418.873	53	328.658			
Total	433200.000	57				

In this sample from MATH 1108, it was clear that both female and male students learned from both treatments but their performance was different as shown in Figure 10. Male students' performance in the GT group ($M = 91.36$, $SD = 14.68$) was higher than their performance in the GN group ($M = 85.56$, $SD = 18.78$), but it was not statistically significant. Female students in the GT group ($M = 88.33$, $SD = 14.04$) also outperformed those in GN group ($M = 78.68$, $SD = 22.48$), but it was also not statistically significant. In addition, male students in this sample ($M = 88.75$, $SD = 16.45$) non-significantly outperformed female students ($M = 83.38$, $SD = 19.22$) overall and in both treatment groups as shown in Table 6.

Table 6

Means and Standard Deviations for Students' Scores in MATH 1108 by Gender and Modality

Group		*n*	*M*	*SD*
Graphics and written text (GT)				
	Female	18	88.33	14.04
	Male	11	91.36	14.68
	Total	29	89.48	14.101
Graphics and narration (GN)				
	Female	19	78.68	22.48
	Male	9	85.56	18.78
	Total	28	80.89	21.26
Total				
	Female	37	83.38	19.22
	Male	20	88.75	16.45
	Total	57	85.26	18.33

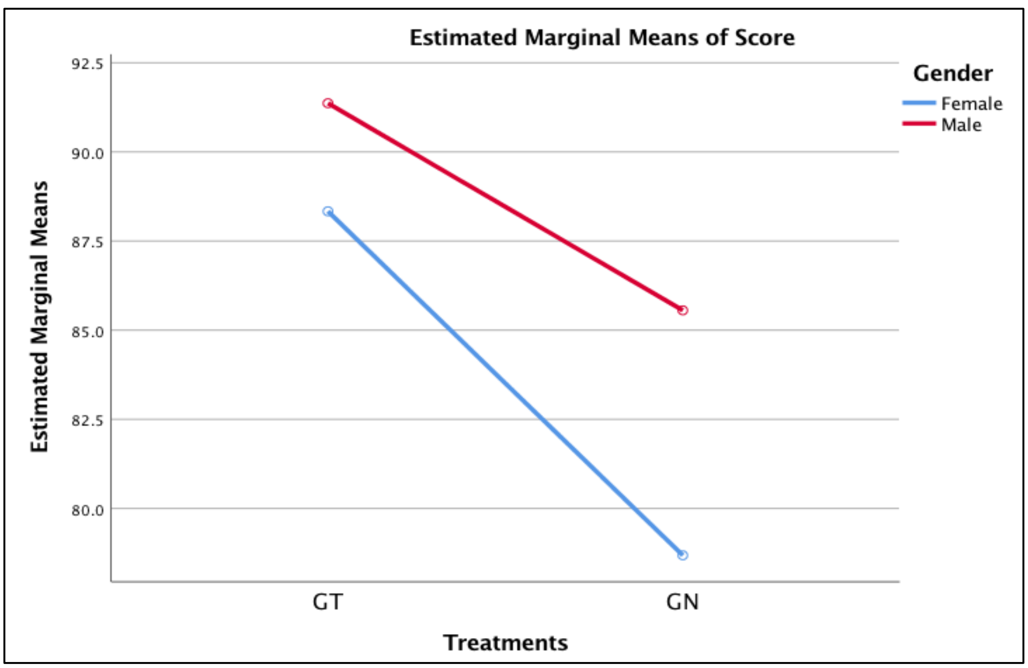


Figure 10. Interaction between modality and gender for students' scores of MATH 1108.

The three ANOVA assumptions were also checked for the sample from MATH 0025, and they were identical to the previous results. The homogeneity assumption was met based on the results of the Brown-Forsythe test, F (3, 47) = 1.72, p = .16. The results of the Shapiro-Wilk test indicated that the normality assumption was not met W = .92, p = .003 (see Figure 11). As mentioned above, ANOVA test is still robust with the violations of normality and this violation does not invalidate the results (Montgomery, 1991; Ramsey & Schafer, 2002). Also, a logarithmic transformation of data was conducted but have the same conclusion. The independence assumption for this sample also had the same techniques were applied to the whole study.

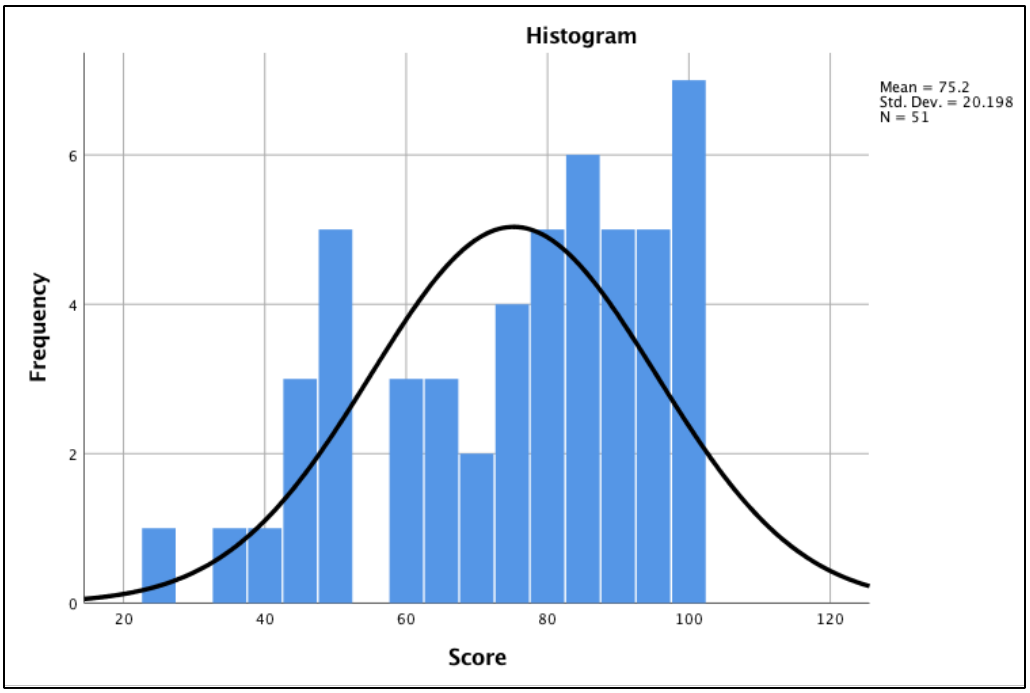


Figure 11. Students' scores distribution in the sample from MATH 0025.

Another statistical test of two-way ANOVA was run to answer the same research questions for the sample from MATH 0025 (see Table 7). The results were not different from the previous statistical tests. There was no statistically significant main effect for modality, $F(1, 47) = .74$, $MSE = 387.10$, $p = .39$, $\eta^2 = .016$, or gender $F(1, 47) = 3.29$, $MSE = 387.10$, $p = .08$, $\eta^2 = .065$. The results also found no statistically significant interaction effect between modality and gender *F*(1, 47) = .53, *MSE* = 387.10, *p* = .47, η^2 =.011.

Table 7

Two-Way ANOVA for Students' Scores of MATH 0025

Dependent Variable: Students' Scores						
Source	***SS***	***df***	***MS***	***F***	***p***	**Partial η^2**
Intercept	211665.010	1	211665.010	545.529	.000	.921
Gender	1275.979	1	1275.979	3.289	.076	.065
Treatments	288.776	1	288.776	.744	.393	.016
Gender*Treatments	206.144	1	206.144	.531	.470	.011
Error	18235.965	47	387.999			
Total	308775.000	51				

The results of the sample from MATH 0025 indicated that the performance of students in the GN group (*M* = 78.46, *SD* = 20.92) was higher than those in GT group (*M* = 71.80, *SD* = 19.25), but it was not statistically significant (see Figure 12). Female students of this sample in general (*M* = 78.24, *SD* = 17.69) were superior than male students (*M* = 67.14, *SD* = 24.63) but it was not statistically significant. As seen in Table 8, there was no large difference between male students' performance in the GT group (*M* = 66.67, *SD* = 22.06) and those in the GN group (*M* = 67.50, *SD* = 27.90). Female students in the GN group (*M* = 83.33, *SD* = 15.53) outperformed female students in GT group (*M* = 73.42, *SD* = 18.64), but also not to a statistically significant level.

Table 8

Means and Standard Deviations for Students' Scores in MATH 0025 by Gender and Modality

Group		*n*	*M*	*SD*
Graphics and written text (GT)				
	Female	19	73.42	18.64
	Male	6	66.67	22.06
	Total	25	71.80	19.25
Graphics and narration (GN)				
	Female	18	83.33	15.53
	Male	8	67.50	27.90
	Total	26	78.46	20.92
Total				
	Female	37	78.24	17.69
	Male	14	67.14	24.63
	Total	51	75.20	20.20

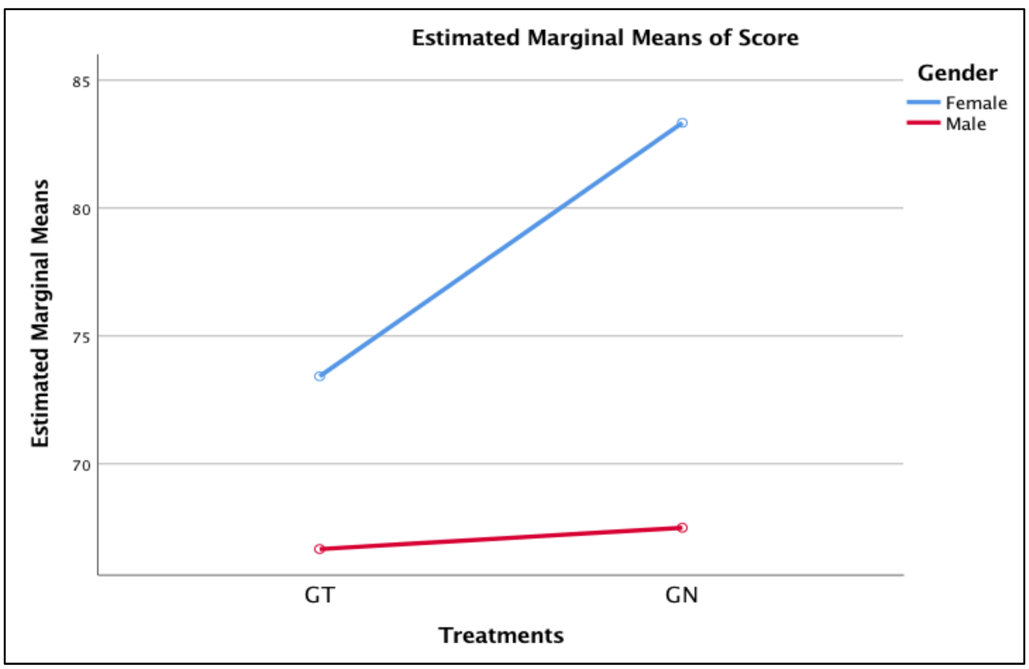


Figure 12. Interaction between modality and gender for students' scores of MATH 0025.

Moreover, the previous statistical test results regarding the samples from MATH 1108 and MATH 0025 showed students' performances were different from a sample to the other. In order to examine whether this difference has significance, an independent sample *t*-test was conducted to compare overall means of these two samples. As shown in Table 9, the results of the independent *t*-test was statistically significant, $t(106) = 2.72$, $p < .05$, $d = .52$. These results mean there was a significant mean difference in students' posttest scores between students in the MATH 1108 and MATH 0025. Students from MATH 1108 ($M = 85.26$, $SD = 18.33$) outperformed students from MATH 0025 ($M = 75.20$, $SD = 20.20$). And the magnitude of the effect size was medium. This significant difference might have been predicted due to the difference between two levels of students in MATH 1108 and MATH 0025. This will be discussed more thoroughly in Chapter V.

Table 9

The Independent Sample t-test on Posttest Between Two Samples from MATH 1108 and MATH 0025

Samples				*t*	*df*	Sig. (2-tailed)
MATH 0025 (*n* = 51)		MATH 1108 (*n* = 57)				
M	SD	M	SD			
75.20	20.20	85.26	18.33	2.72	106	.008

Summary of the Results

This study was intended to test the effects of modality across gender on mathematics learning. The results of two-way ANOVA revealed that modality and gender did not have a significant effect on student achievement. Also, there was no significant interaction effect between modality and gender on student achievement.

Although modality did not show an effect on student achievement, students learned from both treatments. Gender did not have a significant effect on student achievement, and the overall difference between gender performance was small, favoring female students (d = .05). The effect size was small.

An additional statistical analysis was conducted to investigate the research questions based on the level of the course. Two-way ANOVA tests were run for the sample from MATH 1108 and MATH 0025 separately. The results of these two tests were similar. The results indicated that there was no significant effect for modality or gender on student achievement in both samples. Furthermore, no significant interaction effect was found in both samples.

A significant difference was found between two samples from MATH 1108 and MATH 0025, as resulted from the independent *t*-test. Students' performances in the MATH 1108 were superior than those in the MATH 0025. The significant difference between MATH 1108 and MATH 0025 samples indicated that by adding students with lower achievement group to the sample, the variability of the sample was increased. This may have obscured obtaining the statistically significant results.

CHAPTER V

Conclusions

The purpose of this study was to test the effects of modality across gender on mathematical function learning for undergraduate students. The treatment in this experiment explained the concept of functions and function notation through two different methods. These methods were graphics and narration (GN) and graphics and written text (GT). Participants in this experiment were first blocked by gender and then randomly assigned into one of these two treatments. The concept of functions and function notation was selected from an Intermediate Algebra course (MATH 1108).

This chapter will provide discussion about the results of this study with explanations about the potential meaning of these results. In particular, this chapter provides discussion about the results of each research question, recommendations for future practice, and recommendations for future research.

Discussions of the Results

Based on the purpose of this study, three research questions were written to guide the experiment of this study. As explained in Chapter III, different methods were used to recruit students from MATH 1108 and MATH 0025 courses to participate in this study as volunteers. In particular, an email message was sent more than two times to all the students from both courses. However, only 108 participants out of the possible 1258 students joined the study, which was only 8.4% of the course population. The data collection period was over two months due to the difficulties of promoting students to join the study. The lack of students' responses to join the study may due to that the participation was not required for class, no extra credit was offered for MATH 1108 students, their busy schedules, or poor interest to do a short additional activity.

It is clear that the number of participants was very small compared to the enrollment number of students in both courses. Therefore, this small sample may not represent the whole population from both courses. The small sample size also decreased the statistical power. The results of this experiment addressed the research questions as described in Chapter IV. The following sections discuss in depth the findings of each research question and provide more interpretation about the meaning of the results.

Research question 1. Is there a main effect of modality on student achievement, as measured by the scores of students, who learn an "Introduction to Functions and Function Notation" through graphics and narration (GN), as compared to those who learn through graphics and written text (GT)? The results of the first research question found no statistically significant main effect for modality. The most direct interpretation of this result is that this study found no evidence that modality had any effect on student achievement on functions and function notation through two different treatments (GT – GN).

This outcome is in contrast with the hypothesis that the modality principle has an impact on learning. This hypothesis was developed based on prior research which indicated that people learn better when words in multimedia instructions presented as a narration rather than on-screen text (the modality principle) (Clark & Mayer, 2011; Mayer, 2001; Mayer & Moreno, 1998; Moreno & Mayer, 1999; Sweller, Van Merrienboer, & Pass, 1998). In particular, the results of the current study also contradict the prior studies on the effect of modality on mathematics learning (Atkinson, 2002;

Jeung, Chandler, & Sweller, 1997; Mousavi, Low, & Sweller, 1995). Although the treatment in this study was designed based on the conditions of the modality principle (Ginns, 2005; Reinwein, 2012; Sweller, Ayres, & Kalyuga, 2011), the results did not detect the effect of modality on student achievement. Therefore, it is necessary to examine the possible reasons behind these results.

One possible explanation of the results is that sample sizes within groups were relatively small. The small size reduced the power and made it difficult to detect the effect of modality on student achievement. Although several methods were used to promote students' participation in the study as discussed in Chapter III, they did not generate the desired number of participants. In a factorial design, a large sample size within and between groups is essential to observe a significant difference between groups (Myers, Well, & Lorch, 2010).

The length of the study could be one of the potential explanations for the result of the first research question. The treatment of this study was only two weeks. So, participants were given the instruction of one concept of Algebra (functions and function notation) during two weeks. Throughout this short period of time, participants had to study the concept of functions and function notation and complete the posttest in an online environment. Teaching one concept of Algebra online in a short duration may not enough to observe the effect of modality.

In addition, one possible explanation of the results is the addition students from a second course (MATH 0025) to the experiment due to an insufficient number of MATH 1108 participants. The level of MATH 0025 materials was lower than MATH 1108 and this difference may have increased the variation between samples. As shown in Chapter

IV, a significant difference was found between the means of these two groups. The difference between these two groups may have caused an increase in variability that might have obscured the effect of modality on student achievement.

Moreover, some of the literature research indicated that female students may have less confidence than males in mathematics performance (Jones & Jones, 1989; Ross, Scott & Bruce, 2012). The difference in confidence is not necessarily related to the student's ability to learn mathematics concepts, but rather to their view of their ability (Mura, 1987). Based on this, the potential lack of female's confidence in mathematics learning could have been a motivator for them to join the study – in order to get extra support on learning functions and function notation. This could explain the higher percentage of female participants in this study. This rate of female participation led to examining possible gender differences in learning style preferences.

With this point in mind, research indicated that there is a difference between female and male students in learning styles preferences (Dobson, 2010; Wehrwein, Lujan, & DiCarlo, 2007). Most male students may prefer to learn through the multimodal of instructions (Dobson, 2010; Wehrwein et al., 2007), whereas a majority of female students may favor learning through a single mode of instruction (Wehrwein et al., 2007). Dobson (2010) also suggested that this issue is not settled by noting that female students may have equal preferences for the multimodal and single mode of instructions. Another possible explanation the absence of a statistically significant effect of modality in this study may due to the high percentage of female participants (68.5% female students), who may prefer learning through a single mode of instruction. This conclusion was similar to Mattis's (2012) results where the majority of participants were female students (83% female students) and they preferred visual learning over dual modality learning.

Based on the low participation level, especially from MATH 1108 students, it should be noted that participants who joined the study could be those students who wanted to get help in learning the concept of functions and function notation. Therefore, participants' achievement levels could be lower than for the rest of their classes. They may not fully represent the population of the study. In the light of this sample, it may be difficult to discern the effect of modality on student achievement.

Research question 2. Is there a main effect of gender on student achievement between those who learn an "Introduction to Functions and Function Notation"? The result for the second research question revealed that no statistically significant main effect for gender on student achievement. The most direct interpretation of this result indicates that no difference was observed between female and male students when they were studying functions and function notation in the online environment.

It is clear the results of the second research question, which found no differences between genders, are not in agreement with some prior studies on this topic that found gender differences in mathematics learning favoring male students (Anglin, Pirson, & Langer, 2008; Benbow & Stanley, 1980; Lindberg, Hyde, Petersen, & Linn, 2010; NAEP, 2015; Schwery, Hulac, & Schweinle, 2016; Valentine, 1998). Although research studies since the 1970s have found a gender differences on mathematics achievement, this difference appears to be small (Lindberg et al., 2010; NAEP, 2015; Schwery et al., 2016; Valentine, 1998). In contrast to most of the prior literature, the results of the present study did not detect any difference in gender performances at all. In light of this apparent difference between the current study and previous studies, it is worthwhile to examine potential explanations for these results.

The percentage of male students in this study was lower than female students (31.5% male vs. 68.5% female). As discussed in Chapter IV, the percentages of female students in MATH 1108 and MATH 0025 courses (61% female vs. 39% male in MATH 1108 and 67% female vs. 33% male in MATH 0025) were higher than male students. The percentage of female students in this sample was higher than their percentages in both of the classes. Attracting an overabundance of female students in this sample could be partially explained by the female majority in the individual classes and university as a whole. Therefore, it may be difficult to detect gender differences with a high proportion of female participants compared to a low percentage of male participants in this study.

Researchers have found evidence that poor mathematics performance may be related to the teachers' attitude toward students' performance (Ma & Xu, 2004; University of Chicago, 2010). In other words, the mathematics teacher may affect students' performances by conveying to students a stereotype that females' performance is less than males in learning mathematics. In the current study, the effect of teachers' attitude on students' performance was absent because this experiment was delivered in an asynchronous online environment. Therefore, online environments may contribute to preventing any teacher's influence on students' performance, which might have helped female students to learn better, leading to finding no gender differences.

Although this experiment did not study the effect of female or male voiced narration, it should also be clarified that the narration in the GN treatment was recorded by a male voice. Since this study collected no data on this topic, the narrator's male voice can't be eliminated as a potential cause of influence to either gender.

In addition, gender differences may be associated with the social environment, which may not support female students in mathematics learning (Fennema & Sherman, 1977; Samuelsson & Samuelsson, 2016; Schwery et al., 2016). In a social learning environment, female students may have less confidence due to their view of themselves or their teachers' belief toward their ability in mathematics learning (Jones & Smart, 1995). However, this study was completed through an asynchronous, online environment, where there was neither student-student nor teacher-student interaction. This online environment eliminated the effect of social interactions and the teacher's influence on student achievement. Therefore, this online environment may have prevented social interaction from decreasing female students' confidence in learning the functions and function notation content. This may have reduced any potential gender differences below the point of detection under these conditions.

Another possible explanation is that female students may not have experienced an elevated level of mathematics anxiety in this study. Based on the prior literature, female students may have a higher level of mathematics anxiety than males, which may reduce their performances (Devine, Fawcett, Szűcs, & Dowker, 2012; Ma & Xu, 2004). However, participants joined this study as volunteers and this experiment was an extra activity, so it did not affect their course grades. Therefore, it might be supposed that the volunteer aspect of the design may have helped reduce anxiety. In addition, all participants had completed the experiment individually through the online environment. As discussed above, the lack of interaction with the teacher and students may have supported female students to reduce any potential teacher's anxiety and thus feel more comfortable in performing in this experiment. As shown in Chapter IV, female students had learned from this experiment at the same statistical level as males. Thus, the use of technological tools in online environments may reduce students' anxiety and lead to positive learning (Sun & Pyzdrowski, 2009; Taylor & Mohr, 2001). In this situation, it may be difficult to discover gender differences, if they exist at all.

Research question 3. Is there an interaction effect on student achievement due to the combination of modality (GT – GN) and gender (M – F)? The findings of this research question showed no statistically significant interaction effect between modality and gender on student achievement. The most direct interpretation of this conclusions clarified the combination of modality and gender did not affect students' performance on learning functions and function notation. This conclusion challenged the hypothesis that there would be an interaction effect on student achievement due to the combination of modality and gender. These findings also reverse the results of Flores, Coward, and Crooks (2010), which found an interaction between modality and gender.

The lack of interaction effect may due to the low statistical power that caused by the sample sizes within groups and the wide variation. Although the interaction effect was not statistically significant, the results of this study indicated that the performance of female and male students was very different from each other (see Figure 8). Male students' performance in the GT group (M = 82.65, SD = 20.85) was higher than female students (M = 80.68, SD = 17.96). However, female students' performance (M = 80.95, SD = 19.29) was higher than that of male students (M = 77.06, SD = 24.56) in the GN group. As can be seen in Figure 8, there was an interaction effect but it was not statistically significant. This may due to that the sample sizes within groups were small. The non-statistically significant interaction in this study may indicate that a possible interaction may be found with a larger sample size.

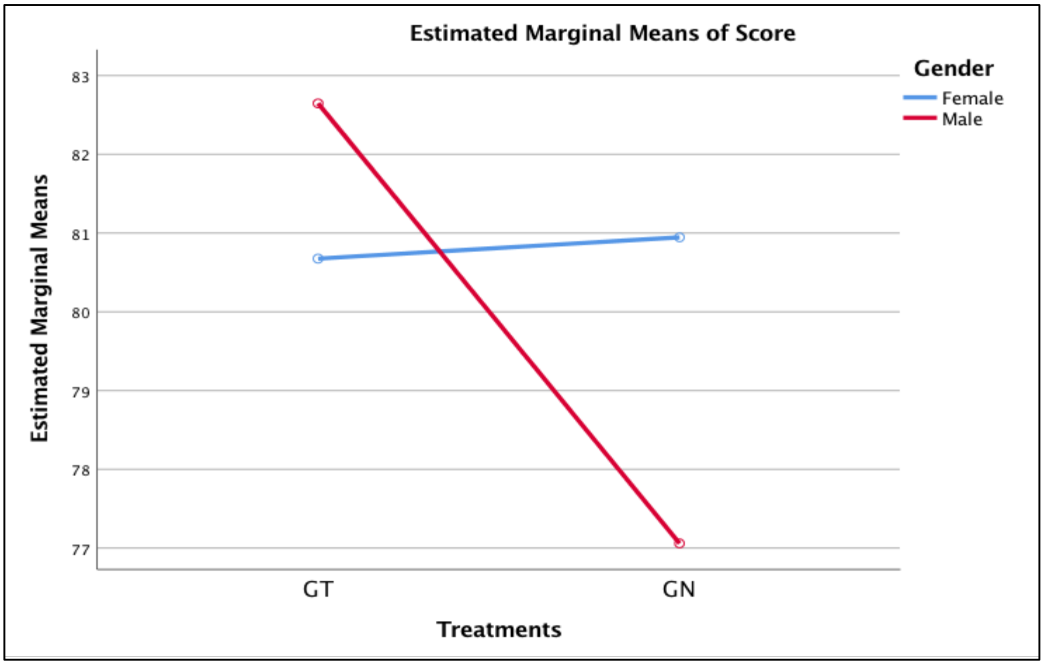


Figure 8. Interaction between modality and gender.

Recommendations for Future Practice

This study examined the effects of modality across gender by illustrating functions and function notation through two different methods (GT – GN). The research on the applications of the modality principle in teaching Algebra to undergraduate students is still few. This study, by itself, is insufficient to state that there is no effect of modality. Therefore, it is recommended, based on prior research (Clark & Mayer, 2011; Jeung, Chandler, & Sweller, 1997; Mousavi, Low, & Sweller, 1995; Sweller, Van Merrienboer, & Pass, 1998), that instructional designers as well as mathematics instructors should consider the applications of the modality principle in their design of instructions. The conclusions of this study highlighted various ideas for future practice, which can be applied by designers. These ideas are discussed in the following paragraphs.

The modality principle can be applied to reduce the overload on visual channel. As discussed in Chapter II, Clark and Mayer (2011) stated that the modality principle can be used when complex graphics and their verbal commentary are presented together at the same time. The instructor of the Intermediate Algebra course (MATH 1108) considered the functions and function notation one of the difficult topics for students in this class. However, some students may have considered the function graphics complex while others considered them not complex. If a part of the sample did not consider the graphics to be complex, the effect of modality might have been reduced in this study.

Although the treatments of this study involved the conditions of the modality principle, no effect was found. Perhaps the topic, and the associated graphics, for this study may not of a high level of difficulty for participants in this study. Thus, it is recommended for future practice that mathematics instructors should use the modality principle to explain other topics of Algebra, which include complex graphics and verbal information.

In addition, since this study showed no main effect for modality and gender, it may be possible to have choices of different types of instruction. These instructional types may include an instruction with graphics and text or graphics and narration. The narration can be recorded by male or female voice. Female and male students can choose their preferred type of instruction.

The online learning environment may have reduced students' anxiety, which could help them to increase their confidence in themselves to learn mathematics. Mathematics instructors might take advantage of online environments by offering some instruction and practice online. Designing online instruction may require mathematics instructors to work with instructional designers in order to create well-designed instruction and practice.

The instructional design processes used in this experiment were based on the Kemp's model. This model detailed the instructional design process and focused more on the formative evaluation. Thus, future practice should carefully examine the situations where the modality principle can be applied. Also, it is recommended to ensure practices are well designed based on the instructional design process.

Recommendations for Future Research

Based on the literature review, few studies had been conducted to examine the effects of modality across gender on learning mathematics with undergraduate students. This study contributed to fill the gap of the literature by adding some information about the implementation of the modality principle as well as gender differences in learning mathematics. Although no statistically significant main effect was found for modality or gender in this study, the implication of this study provided more directions for future research that should be done.

The present study failed to find a statistically significant effect for modality on student achievement. As discussed previously, it should be noted that sample sizes within groups were small and the addition of the second-course students (MATH 0025) may have caused a wide variation between samples. Based on this, it is recommended to repeat this study with more focus to get a larger number of participants from undergraduate students in the MATH 1108 course. Perhaps a larger sample size from MATH 1108 students may increase the power and limit the variation. It may provide evidence regarding the effect of modality.

The findings of this study indicated that students from MATH 0025 may not be ready for the learning of functions and function notation at this level. Therefore, they should not be included in future research of examination content of MATH 1108. It will be possible to replicate this study with a content of MATH 0025 and full participation from students who enrolled in this course.

This study examined only one unit of Algebra content. The concept of functions and function notation was chosen for this study based on the recommendations of the MATH 1108 instructor and coordinator. This concept was considered one of the more difficult subjects for students. Future research should replicate this study with different units of Intermediate Algebra, or the entire course, to determine whether or not it will give the same results.

No evidence of gender differences was found in this study. The high proportion of female participants in this study may have obscured any existence of gender differences. Future research should have a balanced number of female and male students from the course (MATH 1108). Equal gender numbers in a study may help to obtain more accurate information on gender differences in mathematics learning.

There was no main effect for modality, gender, or their interaction found in this study. However, both female and male students learned from both treatments. The online environment may have provided an opportunity for students to learn equivalently and it may have limited gender differences. Perhaps online environment could be a factor that has an equalizing effect on gender differences. It is recommended future research examine whether or not online environments have an effect on gender differences in mathematics learning, especially with undergraduate, post-secondary students.

Summary

This study was conducted to examine the effects of modality across gender on mathematics learning for undergraduate students. Cognitive Load Theory (CLT) and Cognitive Theory of Multimedia Learning (CTML) were used as frameworks for this study. The concepts of functions and function notation were selected from the Intermediate Algebra course (MATH 1108) to be examined in this study. This study included two different treatments: (a) graphics and narration (GN) and (b) graphics and written text (GT). The Kemp model was used to design the treatments based on the instructional design process. Both instructional treatments taught the same materials of functions and function notation but by different methods. All the treatments and instruments were delivered online.

Data gathered from this study were analyzed by using a factorial ANOVA test to answer three research questions. The results of two-way ANOVA indicated that no statistically significant effects were found for modality or gender on student achievement. The results also showed there was no significant interaction between modality and gender on student achievement.

This study included participants from two different courses: Intermediate Algebra (MATH 1108) and Elementary Algebra (MATH 0025) courses. Therefore, additional statistical tests were conducted to examine research questions based on the level of course. The results of these tests also found no significant effect for modality or gender on student achievement in each sample. In addition, no significant interaction between modality and gender on student achievement was found in each sample. However, a result of the independent *t*-test showed a significant difference between two samples from MATH 1108 and MATH 0025. Students from MATH 1108 performed at a higher level than those in MATH 0025.

The conclusions of this study highlighted recommendations for future research. This study can be replicated with a larger number of students from the same level of Algebra course. It can be done also with different topics of Algebra. Furthermore, this study can be conducted with a focus to get a balanced number of female and male students to get more information about gender differences in mathematics learning.

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APPENDIX A

Learners Characteristics Profile

Consideration	Response	Revisions to Response
Physical Age Range:	Participants were 18 years old or above. However, the designer does not see this alteration as a significant factor in the materials development or implementation of the project.	
Educational Range:	Undergraduate students	Department of Mathematics & Statistics at the institution
Cognitive Range:	Undergraduate students	
Prerequisite Knowledge/Skills:	Since students have the high school level, it was assumed they have skills and knowledge related to basic computer use, including word processing, spreadsheets, and e-presentations. Since they were enrolled in a college course, it was assumed they have necessary skills for academic reading and writing.	
Group Dynamics:	Students were undergraduate students, and some of them were freshmen students. Some of the targeted learners came from different states or countries. So, they may have various educational backgrounds, but all speak English and study the same materials.	
Learning Style Preferences:	This course was delivered online. Both visual and and visual-auditory learning were provided for the purpose of this study. The designer included close captioning for video materials in the GN treatment. Also, visual learning was available in the GT treatment. In addition, participants' learning style preferences were not examined in the analysis phase.	

Motivational Factors:	Since the institution was using Moodle as a learning management system, learners would be motivated to join this course because this study was online. Also, incentive points such as gift cards were offered. Students' interest to learn the function and function notation could be a motivator for them to join the study.	
Attitudinal Factors:	Since this course was online, some learners might have a negative attitude due to their experiences with online courses, while others could have positive attitudes. Therefore, all the necessary guidance and directions were available in Moodle page.	
Environmental Factors:	This course was online. So, it provided some online activities for learners. High speed internet, computer, and headphone were required.	

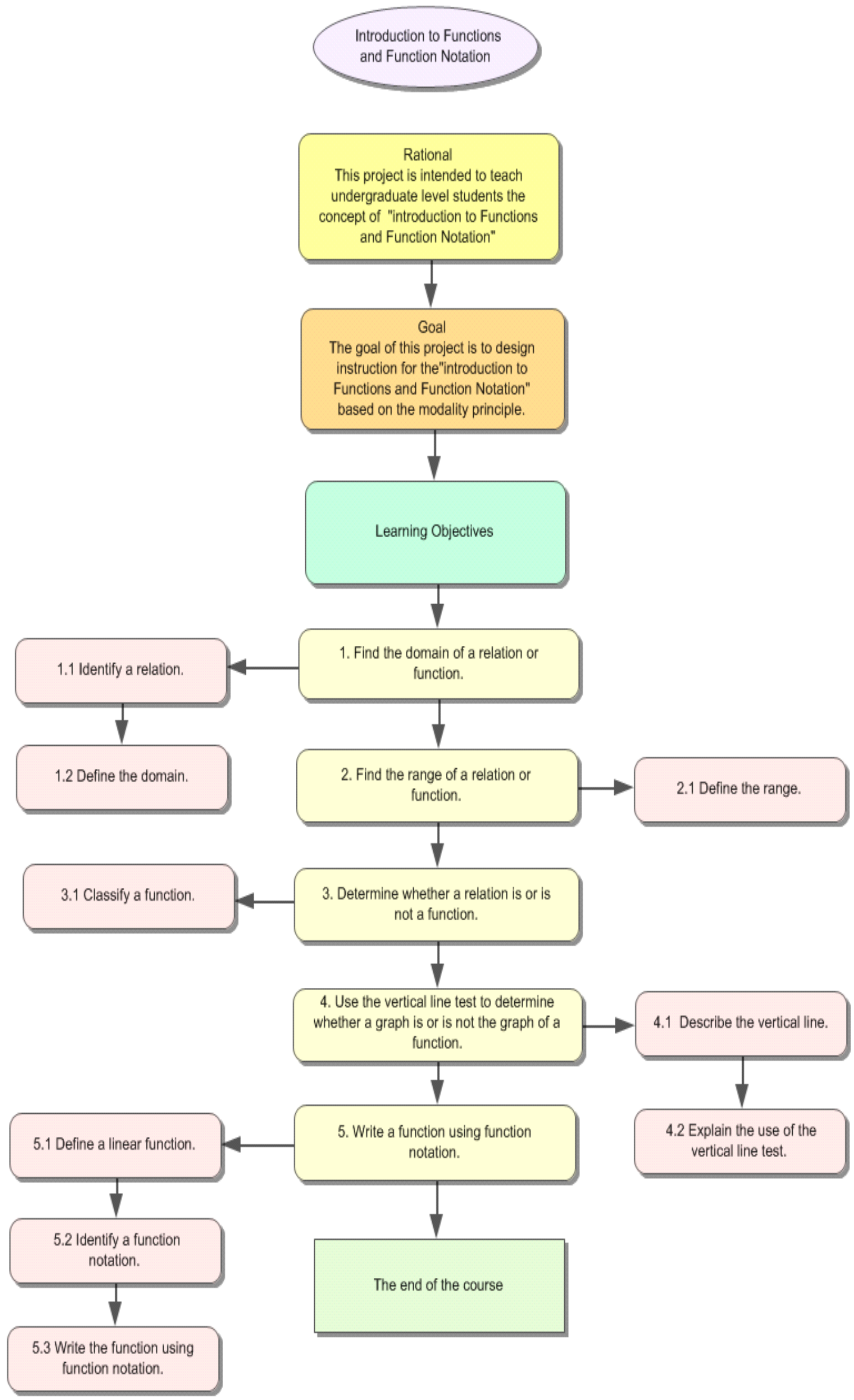
APPENDIX B

Task Analysis

Task/Subtask	Knowledge Type **(D, P, S)**	Prerequisite **(Y/N)**	Environmental Factors **(T, E, M, P, L)**	Domain Type **(C, PM, A)**	Importance **(H, M, L)**	Difficulty **(H, M, L)**
Objective 1: The student will be able to find the domain of a relation or function.						
1.1 Identify a relation.	D	N	E, M, L	C	H	M
1.2 Define the domain.	D	N	E, M, L	C	H	M
Objective 2: The student will be able to find the range of a relation or function.						
2.1 Define the range.	D	N	E, M, L	C	H	M
Objective 3: The student will be able to determine whether a relation is or is not a function.						
3.1 Classify a function.	D	Y	E, M, L	C	H	M
3.2 Determine whether a relation is or is not a function.	S	Y	E, M, L	C	M	L
Objective 4: The student will be able to use the vertical line test to determine whether a graph is or is not the graph of a function.						
4.1 Describe the vertical line.	D	N	E, M, L	C	M	M
4.2 Explain the use of the vertical line test.	S	Y	E, M, L	C	L	L
Objective 5: The student will be able to write a function using function notation.						
5.1 Define a linear function.	D	N	E, M, L	C	M	L
5.2 Identify a function notation.	D	N	E, M, L	C	M	M
5.3 Write the function using function notation.	P	Y	E, M, L	C	H	H

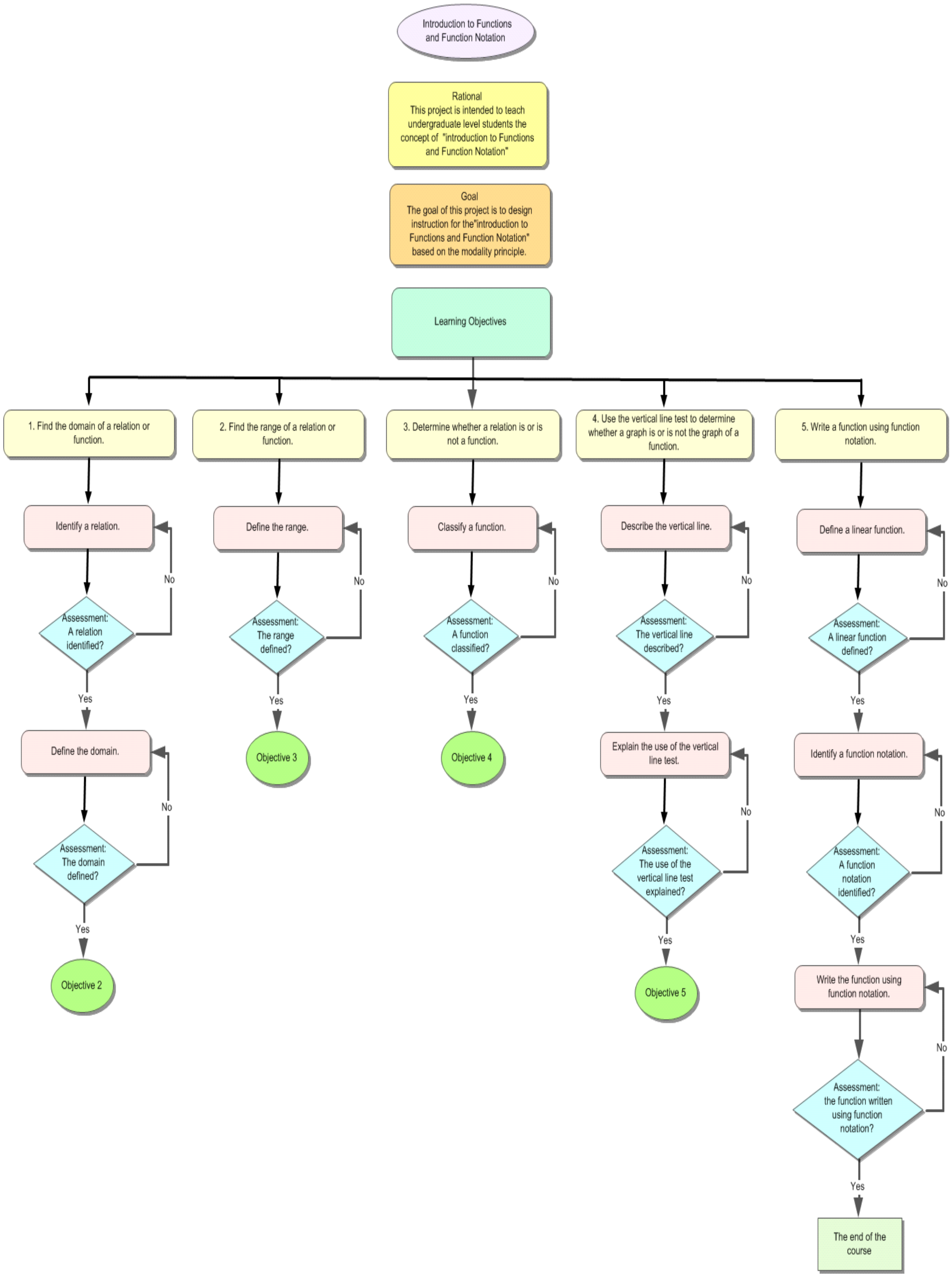
APPENDIX C

Learning Hierarchy


Introduction to Functions and Function Notation
Rational
This project is intended to teach undergraduate level students the concept of "introduction to Functions and Function Notation"
Goal
The goal of this project is to design instruction for the"introduction to Functions and Function Notation" based on the modality principle.
Learning Objectives
1. Find the domain of a relation or function.
1.1 Identify a relation.
1.2 Define the domain.
2. Find the range of a relation or function.
2.1 Define the range.
3. Determine whether a relation is or is not a function.
3.1 Classify a function.
4. Use the vertical line test to determine whether a graph is or is not the graph of a function.
4.1 Describe the vertical line.
4.2 Explain the use of the vertical line test.
5. Write a function using function notation.
5.1 Define a linear function.
5.2 Identify a function notation.
5.3 Write the function using function notation.
The end of the course

APPENDIX D

Flowchart


Introduction to Functions and Function Notation
Rational
This project is intended to teach undergraduate level students the concept of "introduction to Functions and Function Notation"
Goal
The goal of this project is to design instruction for the"introduction to Functions and Function Notation" based on the modality principle.
Learning Objectives
1. Find the domain of a relation or function.
2. Find the range of a relation or function.
3. Determine whether a relation is or is not a function.
4. Use the vertical line test to determine whether a graph is or is not the graph of a function.
5. Write a function using function notation.
Identify a relation.
Assessment: A relation identified?
Define the domain.
Assessment: The domain defined?
Objective 2
Define the range.
Assessment: The range defined?
Objective 3
Classify a function.
Assessment: A function classified?
Objective 4
Describe the vertical line.
Assessment: The vertical line described?
Explain the use of the vertical line test.
Assessment: The use of the vertical line test explained?
Objective 5
Define a linear function.
Assessment: A linear function defined?
Identify a function notation.
Assessment: A function notation identified?
Write the function using function notation.
Assessment: the function written using function notation?
The end of the course
Yes
No

APPENDIX E

Storyboard

Topic: Introduction to Functions and Function Notation.	**Learning Objectives:** 1. The learner will be able to find the domain of a relation or function. 2. The learner will be able to find the range of a relation or function. 3. The learner will be able to determine whether a relation is or is not a function. 4. The learner will be able to use the vertical line test to determine whether a graph is or is not the graph of a function. 5. The learner will be able to write a function using function notation.
Audience: Undergraduate Students	**Total time required to finish:** Two weeks

Online Instructional Strategies for the Course:

Strategies	The techniques that are used in this course
Orientation to Learning	
1. Provide an overview for entire course	Learners will be introduced to this course by the following: • A welcome statement describes the importance of studying the Introduction to Functions and Function Notation.
2. State goal and main objective	The goal and main objectives of this course are listed.
3. Explain relevance of this instruction	Explain the role of functions and function notation in Algebra in general and why it is important.

4. Assist learner recall of prior knowledge, skills, and experience	The opening discussion asks learners to share their prior experiences regarding the concept of Introduction to Functions and Function Notation. This discussion helps them to share their previous experiences.
5. Provide directions on how to proceed through Moodle	Directions on how to use the Moodle are included.
Motivational Strategies	
1. Establishing inclusion	Instructor gives examples about function.
2. Establishing relevance	
3. Instilling confidence by creating challenging environments	Instructor gives learners world problems to solve. Instructor reinforces students to gain confidence and be able to do their duties.
4. Promote competence and satisfaction	Encourage learners to apply acquired skills to their life.

Storyboard of Each Content Module

The GT Module information	The instructional strategies
Learning objectives of the module: 1. The learner will be able to find the domain of a relation or function. 2. The learner will be able to find the range of a relation or function. 3. The learner will be able to determine whether a relation is or is not a function. 4. The learner will be able to use the vertical line test to determine whether a graph is or is not the graph of a function. 5. The learner will be able to write a function using function notation. **Classification based on Bloom's taxonomy:** 1. Understanding 2. Understanding 3. Applying 4. Applying 5. Analyzing	1. Introduction on the contents and objectives: • Write a welcoming statement and introduction to this unit by using label of Moodle tools. • Learning objectives are listed by using label tool. 2. Present the content: • Use slideshow of PPT to illustrate the concepts of Relation, Domain, Range, Function, Vertical line and Function Notation. • All the contents are divided to three sections (Presentations). • Use just only graphics with text to explain the contents. 3. Learning cues • Highlight key information visually in slideshow. 4. Practice • Provide some practices including questions for more practices. • Use threaded discussion for the Q and A session as needed. 5. Assessment • Use a quiz tool for the formative evaluation after each section. • Give a posttest at the end of the course for summative evaluation. • Quizzes and the posttest including multiple-choices and true/false questions. 6. Feedback • Feedback is provided after each quiz.

Type of learning (Merrill's content types): 1. Concept 2. Concept 3. Principle 4. Principle 5. Procedure	• The instructor provides feedback via thread discussion if needed. • Specific questions will be addressed via email by instructor. • The instructor provides the opportunities to meet with any student online through collaborative learning to address any issue if needed. 7. Remediation • Allow students to review formative assessment and their corresponding responses to understand their errors. • Give students more practices to improve their performance.

GN Module information	The instructional strategies
Learning objectives of the module: 1. The learner will be able to find the domain of a relation or function. 2. The learner will be able to find the range of a relation or function. 3. The learner will be able to determine whether a relation is or is not a function. 4. The learner will be able to use the vertical line test to determine whether a graph is or is not the graph of a function. 5. The learner will be able to write a function using function notation. **Classification based on Bloom's taxonomy:** 1. Understanding 2. Understanding	1. Introduction on the contents and objectives • Write a welcoming statement and introduction to this unit by using label of Moodle tools. • Learning objectives are listed by using label too. 2. Present the content: • Use slideshow of PPT with office Mix to illustrate the concepts of Relation, Domain, Range, Function, Vertical line and Function Notation. • All the contents are divided to three sections (Presentations). • Use just only graphics with narration to explain the contents. 3. Learning cues • Highlight key information visually in slideshow. • Use animations by mouse and pen color on the screen to highlight the important component on the graphics. 4. Practice • Provide some practices including questions for more practices. • Use threaded discussion for the Q and A session if needed.

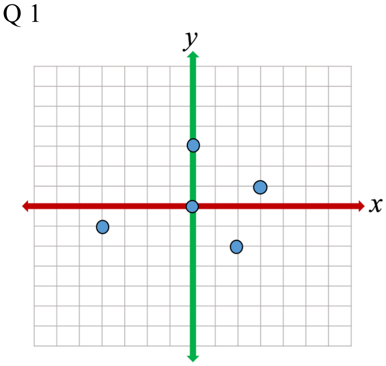
3. Applying 4. Applying 5. Analyzing **Type of learning (Merrill's content types):** 1. Concept 2. Concept 3. Principle 4. Principle 5. Procedure	5. Assessment • Use a quiz tool for the formative evaluation after each section. • Give a posttest at the end of the course for summative evaluation (including multiple-choices and true/false). 6. Feedback • Instructor provides feedback via thread discussions if used. • Specific questions will be addressed via email by instructor. • Instructor can set up an appointment to meet with any student online through Google plus. 7. Remediation • Allow students to review assessment and their corresponding responses to understand their errors. • Give students more practices to improve their performance.

APPENDIX F

Posttest Questions

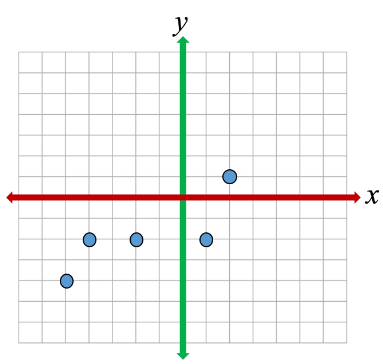
State the domain and range from the graph of the relation.

Q 1



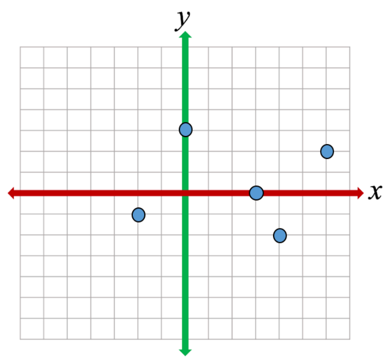
- D = {-4, 0, -2, 3} and R = {-2, -4, 0, -1, 3}
- D = {-2, -1, 0, 1, 3} and R = {-4, 0, 2, 3}
- D = {-4, 0, 2, 3} and R = {-2, -1, 0, 1, 3}
- D = {-4, 2, 3} and R = {-2, -1, 0, 1}

Q 2



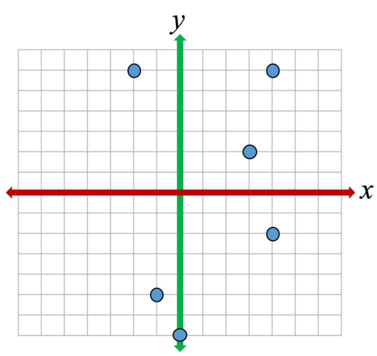
- D = {-5, -4, -2, 1, 2} and R = {-4, -2, 1}
- D = {-4, -2, 1} and R = {-5, -4, -2, 1, 2}
- D = {5, 4, 2, -1, -2} and R = {4, 2, -1}
- D = {4, 2, -1} and R = {5, 4, 2, -1, -2}

Q 3



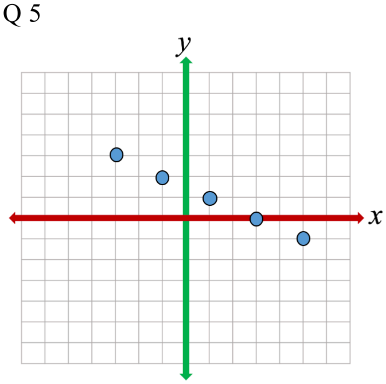
- $D = \{-6, 0, 5, 4, -1\}$ and $R = \{-3, 1, 0, 3\}$
- $D = \{0, 3, -4, 6\}$ and $R = \{-4, -2, 0, 2, 3\}$
- $D = \{-2, -1, 0, 2, 6\}$ and $R = \{-2, 0, 3, 4, 6\}$
- $D = \{-2, 0, 3, 4, 6\}$ and $R = \{-2, -1, 0, 2, 3\}$

Q 4



- $D = \{-2, -1, 0, 3, 4\}$ and $R = \{-7, -5, -2, 2, 6\}$
- $D = \{7, -1, 0, 3, 4\}$ and $R = \{-2, -5, 2, 6\}$
- $D = \{-7, -1, 0, 2, 4\}$ and $R = \{-1, 0, 2, 5\}$
- $D = \{-1, 0, 3, 4, -7\}$ and $R = \{6, -5, 3, 6\}$

Q 5



- $D = \{0, 1, 2, 3\}$ and $R = \{-1, 1, 3, -5\}$
- $D = \{-3, -1, 1, 3, 5\}$ and $R = \{-1, 0, 1, 2, 3\}$
- $D = \{-2, 0, 1, 3\}$ and $R = \{1, 2, 3, 5\}$
- $D = \{5, -1, 1, 0, -5\}$ and $R = \{-3, -1, 1, 2, 3\}$

Indicate whether or not the relation is a function.

Q 6

h **= {(1, -5), (2, -3), (-1, -3), (0, 2), (4, 3)}**

- o Function
- o Not a function

Q 7

f **= {(-1, 4), (-1, 2), (-1, 0), (-1, 6), (-1, -2)}**

- o Function
- o Not a function

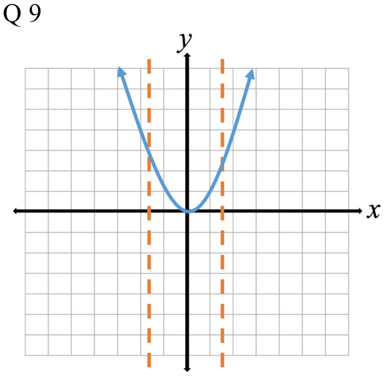
Q 8

g **= {(0, 0), (-2, -5), (2, 0), (4, -6), (5, 2)}**

- o Function
- o Not a function

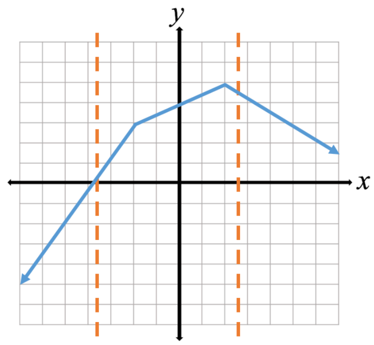
Use the vertical line test to determine whether or not each graph represents a function.

Q 9



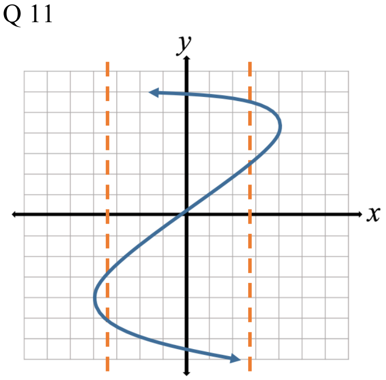
- o Function
- o Not a function

Q 10



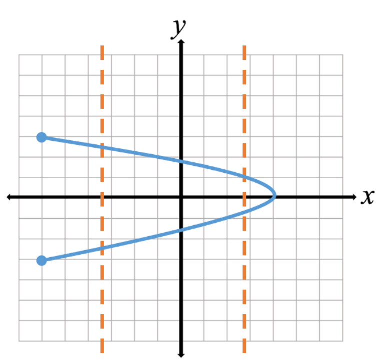
- ○ Function
- ○ Not a function

Q 11



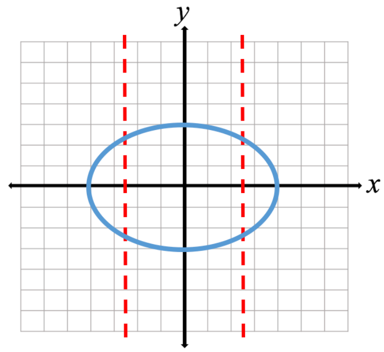
- ○ Function
- ○ Not a function

Q 12



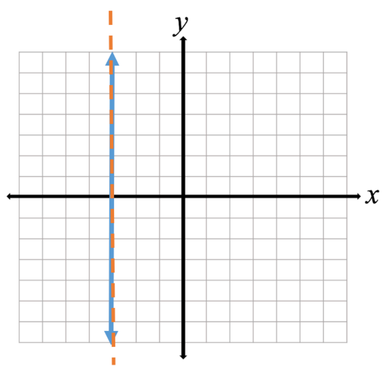
- ○ Function
- ○ Not a function

Q 13



- Function
- Not a function

Q 14



- Function
- Not a function

Find the values of the functions as indicated

Q 15

Given $g\,(x) = -4x + 7$, **find** $g\,(-3)$

- 19
- 5
- 0
- 14

Q 16

Given $g\,(x) = -4x + 7$, **find** $g\,(6)$.

- -17
- 31

- 9
- -3

Q 17

Given $f(x) = 6x^2 - 10$, find $f(0)$.

- -10
- 0
- 10
- -4

Q 18

Given $f(x) = 6x^2 - 10$, find $f(-4)$.

- 86
- 12
- 38
- 96

Q 19

Given $p(x) = x^2 + 4x + 4$, find $p(-2)$

- 0
- -8
- 16
- 12

Q 20

Given $p(x) = x^2 + 4x + 4$, find $p(-5)$.

- 9
- 50
- 5
- 29

APPENDIX G

The Permission for the Materials Use

Idaho State UNIVERSITY

Ali Alhramelah <alhrali@isu.edu>

Hawkes-Request for permission to use materials

Kristen Thompson <kthompson@hawkeslearning.com> Fri, Sep 22, 2017 at 3:25 PM
To: Ali Alhramelah <alhrali@isu.edu>

Hi Ali,

I heard back from my management team here and first off, we want to truly apologize for misunderstanding that you were waiting for a reply on this as we would never have left you without an answer-I just misunderstood your need. There is absolutely no issue with you teaching out of our text for your research and we wish you luck and with your dissertation! We would love to receive a copy of it once it is done!

If there is anything further that I can do to help you with this, please let me know and I will personally make sure this is taken care of.

Have a wonderful weekend.

All the best,

Kristen Thompson|Training & Support

HAWKES LEARNING

Ph: 800.426.9538 |email: kthompson@hawkeslearning.com

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From: Kristen Thompson
Sent: Friday, September 22, 2017 11:31 AM
To: 'Ali Alhramelah' <alhrali@isu.edu>
Subject: RE: Hawkes-Request for permission to use materials

[Quoted text hidden]

APPENDIX H

The Email Message

Dear student:

You are invited to join a study to experience Intermediate Algebra practice in functions and function notations by two different methods. You were selected because you are enrolled into the Intermediate Algebra class (MATH 1108) or the Elementary Algebra class (MATH 0025). This study provides a great opportunity for you to learn the functions and function notation in a different learning environment than your normal class. It also provides an opportunity for you to experience online learning with mathematics content.

This study will be delivered through the institute's learning management system (Moodle), so you can choose when to participate based on your schedule. The study course will be open for two weeks and it will not take more than two hours. This study is totally separate from the class requirements; therefore, refusing participation in this study will have no effect on your grades. Students who will participate and complete the study will be entered into a drawing for gift cards. There will be a gift card for approximately one out of three participants. The value of the gift card is $10.

Please join the study by clicking on the following link to be directed to the study on ISU's Moodle, log in to the Moodle by using your Bengal username and password, and then log in to the study by entering this password: math1108

Link: https://elearn.isu.edu/moodle/course/view.php?id=11518

If you have any questions, please contact the researcher via email at: alhrali@isu.edu.

Sincerely,

Ali Ahramelah

Researcher

APPENDIX I

The Consent Form

Consent Form to Participant in a Research

Dear Participant:

You are being asked to be in this research study of (The Effects of Modality and Gender on Learning the Algebra Concepts *Functions* and *Function Notation* among University Undergraduate Students). You were selected because you are enrolled into the Intermediate Algebra class (MATH 1108) or the Elementary Algebra class (MATH 0025), and this study is demonstrating the concept of functions and function notation by two different methods. *This study is totally separate from the class requirements; therefore, refusing participation in this study will have no effect on your grades.*

Purpose of Study

The purpose of this study is to examine the effectiveness of the modality principle across gender on mathematics learning. This study has two groups: one group will study the concept of functions and function notation via graphics and written text, while other group will study the same contents through graphics and narration (the modality principle). Also, looking to the gender differences in mathematics learning.

Description of the Study Procedures

This study will be delivered through ISU's Moodle site and the information of this study will be kept confidential. If you agree to participate in this study, you will be given access to the Moodle site. There will be three short presentations explaining the concept of functions and function notation. You do not need to have a special effort to master the materials of this experiment, or to communicate any information with each other. You should have your typical and normal effort while you are in the study. After studying the materials, you will have to take a quiz at the end. You have up to two weeks to complete this study. It is flexible time to log in into the course and complete the experiment. Also, you can log in and out during the two weeks based on convenient times for your schedule.

Benefits of Being in the Study

This study provides a chance for you to learn the concept of functions and function notation in different ways. It also helps you to experience online learning when studying mathematics contents.

Participation in this study is completely voluntary, so it is up to you. You have the right to withdraw completely from the study at any time. Participants who completed the study will be entered into a drawing for gift cards. There will be a gift card for each one out of three and the value of this card is equal to $10.

Consent

By clicking on (Yes, I consent to participate in this study) you indicate you are 18 years or older and you have read and understood the information provided above as well as decided to volunteer as a research participant for this study.

1. **Would you like to participate in the study?**

- Yes, I consent to participate in this study.

- No, I choose not to participate in this study.

2. Please identify your gender for examining the gender difference in mathematics learning.

- Female.
- Male.
- Other.