THE EFFECTS OF SEGMENTATION AND SELF-EXPLANATION ON COGNITIVE LOAD AND LEARNING ACHIEVEMENT WITHIN THE CONTEXT OF VIDEO MODELING

by

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(Under the Direction of Robert Maribe Branch)

ABSTRACT

This experimental study examined the effects of four different types of video modeling instruction that adopted segmentation and self-explanation design principles on cognitive load and learning achievement. A pretest was administered before video modeling instruction, and a posttest and a cognitive load survey were administered after the instruction. Multiple linear regressions were used to analyze the mean differences among groups regarding cognitive load and learning achievement. Pearson correlations were used to examine the relationships between students' prior knowledge and cognitive load and learning achievement.

The results revealed that there was no significant effect identified on cognitive load. However, results of learning achievement revealed that the method combining segmentation and self-explanation methods significantly affected students' overall performance and evaluative ability. Also, the segmentation method significantly affected students' evaluative ability.

INDEX WORDS: Cognitive Load, Learning achievement, Segmentation, Self-explanation, Video Modeling.

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DEDICATION

This dissertation is dedicated to my mother, Shuixiu Yi, my father, Yikuang Zheng, my son, Jiahe Wang, my ex-husband, Xingyu Wang, as well as to my siblings.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Increasing access to computers and the internet has provided many new opportunities for designing and implementing meaningful learning experiences for 21st century learners. New opportunities include integrating technology into the classroom. Meaningful technology integration is achieved when teachers effectively use appropriate technologies to help them expand on specific learning content and determine how to best assist students' learning (Brantley-Dias & Ertmer, 2013; Harris, 2005). Technology integration supports students' acquisition of high-order thinking, analysis, and problem-solving skills, and promotes a positive change in teacher-student relationships (U.S. Department of Education, 2003). Meaningful technology integration into education has been identified as an essential professional skill for teachers (U.S. Department of Education, 2003) and one of the most important issues in educational innovation (Hew & Brush, 2007). The ever-increasing implementation of educational technologies in schools implies educational researchers' and professionals' growing attention of effective use of these educational technologies in education.

Despite this increase in scholarly attention, renewed efforts are called in order to better prepare teachers to effectively integrate technology into the classroom (Ertmer & Ottenbreit-Leftwich, 2010). Some teachers are observed not using technology to engage students in deep learning, instead focusing on playing videos in the classrooms or having students search for information on the internet instead of working on inquiry-based activities (Lee & Kim, 2014; Kim, Hannafin, & Bryan, 2007). Such superficial technology integration practices fail to engender the desire for students to engage in learning on a whole new level (Blaire, 2012). This new level of learning demanded by students poses a challenge to teachers to improve their technology integration practices.

Numerous approaches and strategies have been conducted to develop teachers' knowledge and skills regarding how to integrate technology into classrooms, and modeling is one of those strategies. A modeling approach occurs when pre-service teachers are shown exemplary technology integration practice; in turn, pre-service teachers imitate the observed behaviors in their own classroom or add them to their teaching repertoire (Bennett, 1991). Modeling provides specific classroom strategies and increases observers' confidence for generating the same behaviors (Bandura, 1978; Ertmer, 2005; Ottenbreit-Leftwich, Glazewski, & Newby, 2010). Thus, various types of modeling approaches have been examined in technology integration studies in order to ascertain learners' engagement and academic achievement.

Video modeling is one modeling approach that uses multimedia to apply exemplary technology integration practices. Video modeling demonstrates real-life practices without spatiotemporal limits, especially internet-based video modeling that provides learners with abundant time-flexible, self-paced, and free learning resources and opportunities (Mohamed & Rheem, & Abd, 2010; White & Geer, 2013). Therefore, video modeling is believed to have potential in bridging the gap between theoretical knowledge and practical knowledge (Beck, King, & Marshall, 2002; Dieker, et al., 2009; Van den Berg, Jansen, & Blijleven, 2004). Video modeling presents information and knowledge using two different representational modes: verbal and non-verbal, like other formats of multimedia learning approaches. Therefore, video modeling can also vividly present teachers and students' attitudes, emotional responses, behavior patterns, and their interactions involved in teaching practices (Bandura, 1978; Ottenbreit-

Leftwich et al., 2010). Video modeling has been perceived in some cases by learners as a useful approach to learn technology integration (West & Graham, 2007). Thus, video modeling should be considered as an effective instructional strategy for teaching technology integration in university classrooms.

Existing applications of video modeling, as an instructional strategy for teaching technology integration, seem to be limited in terms of student development. One major problem with the existing applications of video modeling is that it has been found to be ineffective for developing students' abilities to critically analyze and evaluate technology integration practices (Dieker et al., 2009; Lee & Kim, 2014; Star & Strickland, 2008). The problem is largely attributed to ineffectiveness in constructing interactive multimedia learning environments (Domagk, Schwartz, & Plass, 2010; Kennedy, 2004; Pedra, Mayer, & Albertin, 2015). Learners are often observed to be passive learners during video modeling, and they do not spontaneously apply cognitive and metacognitive strategies to process the presented information by selecting, organizing, and integrating associated information into a coherent representation (Chi & Wylie, 2014; Hassanabadi, Robatjazi, & Savoji, 2011; Yeh, Chen, Hung, & Hwang, 2010). Thus, instructional scaffolds are necessitated to facilitate learners to actively process dynamic multimedia materials.

There is a need to conduct interactive multimedia learning environments that facilitate a learner's mental interactions with learning content to become an active and constructive learner. Students rarely learn from passively viewing videos (Dieker et al., 2009; Moreno & Mayer, 2007), and learning from viewing a video model by itself is insufficient, especially for novice learners (Kurz & Batarelo, 2010) because knowledge development is mediated through learners' thought processes (Kennedy, 2004; Jonesson, 1988). Learners in video modeling need instructional guidance to facilitate their understanding of the video models (Kennedy, 2004; Kurz & Batarelo, 2010; Mayer, 2014). Learners also need instructional scaffolds to facilitate their interpreting the complexity of teaching practices displayed in the video because the practices presented in the video are often "too detached" (West & Graham, 2007, p.133) from learners' own classroom settings so they do not know what to look for while viewing a video. Thus, there emerges a need for constructing cognitive interactivity for video modeling as a way to develop students' abilities to critically analyze and evaluate technology integration practices.

This study introduces two constructs that promote cognitive interactivity for improving learning outcomes of video modeling: segmentation and self-explanation. Segmentation and self-explanation are two multimedia learning designs that offer learners external supports when learning from video models. The purpose of this study is to contribute to the theory and practice of the interactivity design of video modeling by testing a set of constructs drawing upon the cognitive theory of multimedia learning.

Conceptual Framework

The concept that frames this study was cognitive interactivity (Figure 1). The concept posits that effective cognitive interactivity for facilitating learners' cognitive engagement and generative learning does not automatically occur between learners and the materials to-be-learned. The facilitation of cognitive interactivity demands the use of appropriate instructional strategies during learning. According to Rogers and Scaife (1998), cognitive interactivity refers to mental interactions between external representations and internal representations of the materials to-be-learned when a learner is engaged in a cognitive task. External representations of learning materials can be presented in different media formats, such as texts, graphics, pictures, or video footage (Aldrich, Rogers, & Scaife, 1998; Kozma, 1991). Internal representations refer to the learner's cognitive structure and processing of the materials to-be-learned, such as propositions or schemas (Kennedy, 2004; Paivio, 1990; Rogers & Scaife, 1999). Thus, cognitive interactivity is concerned with interplays between learners and learning information.

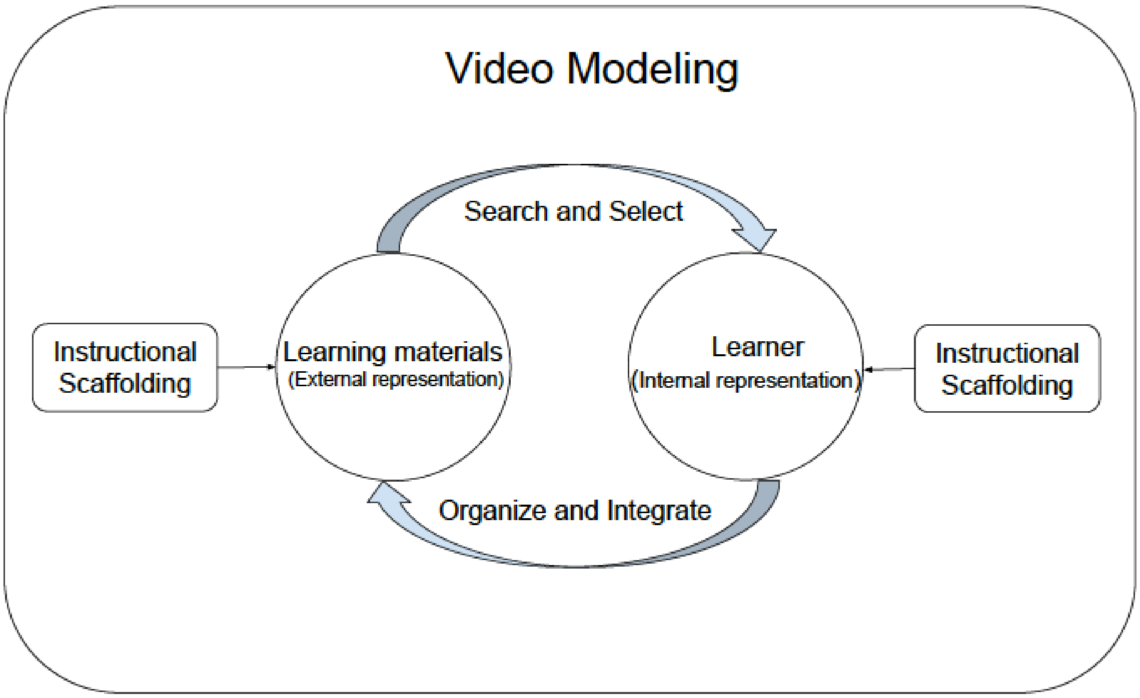


Figure 1. Construction of cognitive interactivity

As is shown in Figure 1, cognitive interactivity is affected by the inherent complexity of learning materials and the completeness of learners' mental structures of the materials (Kennedy, 2014; Rogers & Scaife, 1998). Appropriate instructional scaffolds are expected to help intervene in the cognitive interactivity for facilitating generative learning. Instructional scaffolding refers to the instructional support or guidance tailored to the learning task or learner characteristics to optimize learning and maximize achievement (Delen, Liew, & Wilson, 2014; Vygotsky, 1978). Scaffolding for facilitating cognitive interactivity can be conducted via instructional design in two ways: (1) restructuring the presentation format of the learning materials, and (2) amending the learner's mental structure of the materials to-be-learned by fixing misconceptions or information gaps between the materials and their existing schema (Chi & Wylie, 2014; Yeh, Chen, Hung, & Hwang, 2010; Wouters, Tabbers, & Paas, 2007). Cognitive interactivity in video modeling embraces a series of cognitive processes, including selecting and organizing information relevant to a learning task out of a large amount of verbal and visual information and then integrating associated information with existing knowledge to construct a coherent representation (Mayer, 2010). When selecting instructional scaffolds, researchers should consider what kind of learning implications that these constructs of cognitive interactivity will have on video modeling.

Three Assumptions for Multimedia Learning

There are three assumptions associated with multimedia learning: (1) dual-coding channel, (2) limited working capacity, and (3) active processing. These three assumptions describe how a human mind works when processing multiple external representations of information based on research on cognitive science (Mayer, 2014). Table 1 summarizes these assumptions.

Table 1

Summary of Three Assumptions Associated with Multimedia Learning

Assumption	Definition
Dual-coding channel	Human information-processing systems use separate channels for visual and verbal information.
Limited working capacity	Only a limited amount of cognitive processing takes place in each channel at one time.
Active processing	Generative learning involves substantial cognitive processing demands at the visual and auditory channels.

Adapted from *Nine ways to reduce cognitive load in multimedia learning* (p.44), by Mayer, R, and Moreno, R. (2003). New York, NY: Taylor & Francis Group.

The three assumptions with cognitive processing imply the challenges of facilitating cognitive interactivity within the context of video modeling. First, according to the dual-coding channel assumption, the human information-processing system consists of two separate channels: a visual channel and an auditory channel, for processing visual representations and auditory input; the two systems function separately, while they are related interactively and affect mutually during cognitive processing (Baddeley, 1998). Second, the working memory has a severely limited capacity, and only a limited amount of cognitive processing can take place in each channel at one time (Sweller, 2008; Sweller, Ayres & Kalyuga, 2011). Third, high-level thinking is the constant processing of information, requiring a substantial amount of cognitive processing to take place in the two channels (Mayer, 2014). Thus, the priority for constructing cognitive interactivity is to avoid cognitive overload.

Cognitive Processing and Associated Cognitive Load in Multimedia Learning

The cognitive theory of multimedia learning defines three types of cognitive demands: essential processing, extraneous processing, and generative processing (Mayer, 2014). According to Mayer (2014), essential processing is the mental work dealing with the inherent complexity of the learning materials; extraneous processing is the mental work processing irrelevant learning activities and materials; and generative processing is the mental work of understanding the materials and applying the learned information to solve problems (Mayer, 2014; Sweller, 2005;). Each type of cognitive processing is associated with a different type of cognitive load on the learners' cognitive system. As is shown in Table 2, essential processing imposes the intrinsic cognitive load, and extraneous processing imposes the extraneous cognitive load, while generative processing imposes the germane load on the human's cognitive system.

Table 2.

Summary of Three Types of Cognitive Processing and Associated Cognitive Load

Types of Cognitive Processing	Processing Objectives	Types of Cognitive Load
Essential Processing	Learning materials	Intrinsic load
Extraneous Processing	Learning activities that do not serve instructional objectives	Extraneous load
Generative processing	Learning activities that serve the instructional objectives and are helpful for understanding the content	Germane load

Adapted from *Applying the science of learning to medical learning* (p. 548) by Mayer, R. (2010). Boston, MA: Pearson Allyn & Bacon.

Cognitive load means "the load imposed on working memory by information being presented" (Sweller, 2005, p.28). Cognitive load theory distinguishes three types of cognitive load (Sweller, 2010; Van Merrienboer & Sweller, 2005): intrinsic load, extraneous load, and germane load. Intrinsic cognitive load (IL) refers to the cognitive demands on working memory imposed by the cognitive processing of the inherent complexity of learning materials (Swell, 2010, 2011). According to Sweller (2010), the intrinsic load is fixed and innate to a task and "cannot be altered [by instructional design other than by either changing the basic task or changing knowledge levels" (p. 124) for a given task and given learner knowledge levels. Extraneous cognitive load (EL) refers to the cognitive demands imposed by poor, irrelevant instructions that are not beneficial or even harmful for learning. The germane cognitive load (GL) is the effort facilitated by effective instruction that benefits the construction and automation of schemas and engages learners into working on a given task effectively and efficiently (Sweller, 2010; Van Merrienboer & Sweller, 2005). Like other formats of multimedia learning, the priorities of constructing cognitive interactivity in video modeling should always consider reducing EL minimized and facilitating GL (Leppink, Paas, Van der Vleuten, Van Gog, & Van Merriënboer, 2013; Sweller, 2010, 2011).

Theoretical Framework

This study tested the theory of cognitive interactivity facilitated by two multimedia learning principles—segmentation and self-explanation—within the context of video modeling. The segmentation principle was used to guide the design of instructional scaffoldings for devising and structuring the external presentation formats of learning materials. The self-explanation principle was used to guide the design of instructional scaffoldings that support and facilitate learners' formation of internal representations of learning materials and to make sense of the materials.

Segmentation

Segmentation refers to an instructional technique of splitting a continuous video into smaller parts and allows learners to control the pacing of learning for fully processing information of a segment before moving to the next (Clark, Nguyen, & Sweller, 2011; Mayer, Dow, & Mayer, 2003). One problem with continuous videos is that they can create essential overload (Mayer & Pilegard, 2014), "in which important information continues to be presented even if the learners have not had sufficient time to process it" (Fiorella & Mayer, 2018, p. 2). Because the problem of a continuous video can create essential overload (Mayer & Pilegard, 2014), segmentation is a technique that can reduce complexity of learning by chunking a complex video lesson into management segments. Segmentation design also helps learners manage intrinsic load when the video content is complex, presented a fast pace, or unfamiliar to learners (Fiorella & Mayer, 2018; Mayer, 2014). Moreover, providing system-manipulated segments is a technique that promotes germane load because it allows learners to fully process the information of a segment before proceeding to the next (Clark et al., 2011; Fiorella & Mayer, 2018; Mayer, 2014).

Some empirical studies on segmentation have resulted in positive learning outcomes (Doolittle, 2010; Doolittle, Bryant, & Chittum, 2015; Hasler, Kersten, & Sweller, 2007; Mayer & Chandler, 2001; Mayer & Moreno, 2003). Mayer and Chandler (2001) exposed students to a narrated animation explaining lightning twice in their studies. Mayer and Chandler found that students exposed segmented-whole presentation of the animation performed better in both mean recall and mean application (differ significantly) than those exposed whole-whole presentation of the animation in one study; students exposed segmented-segmented presentation of the animation performed better in mean recall and mean application (differ significantly) than whose exposed whole-whole presentation of the animation in another study. Doolittle et al., (2015) chunked a 9-minute historical inquiry multimedia tutorial into different degrees of segments (i.e., 7, 14, 28 segments), and assigned a different version of the video tutorial to a different research group for viewing. Doolittle et al. found a monotonic increase in mean recall and mean application between the no segment research group, the 7-segment research group, 14-segment research group, and 28-segment research group. Segmentation is an appropriate instructional design principle supported by empirical studies for designing instructional scaffoldings to construct cognitive interactivity in video modeling.

Self-explanation

Self-explanation refers to prompting learners to answer conceptually demanding questions that can orient them toward deeper processing of the presented information and encourages them in making explanations to themselves during learning (Wylie & Chi, 2014; Mayer et al., 2003). "Self-explanation is a constructive, generative learning activity that facilitates deep and robust learning by encouraging students to make inferences using the learning materials, identify previously held misconceptions, and repair mental models." (Wylie & Chi, 2014, p.413). Making self-explanations during learning is an act of active learning in which learners get involved with information presented, cognitively and meaningfully think about it, and analyze, synthesize, and evaluate it (Chi & Wylie, 2014; Bonwell & Eison, 1991; Mayer et al., 2013) rather than just passively receiving it (King, 1993). Sweller (2010, 2011) contends that the use of self-explanation encourages GL in multimedia learning. Self-explanation is a promising design principle that facilitate cognitive interactivity during video modeling.

The self-explanation questions developed in this study are expected to facilitate the cognitive interactivity between learners and learning materials in video modeling. Practices of self-explanation in instruction include providing guiding questions or "pre questions" (Mayer et al., 2003, p.810) tailored to learner characteristics (Wylie & Chi, 2014; Chi & Wylie, 2014; Yeh, Chen, Hung, & Hwang, 2010). Each question contains information not directly given in the content learners (Berthold, Eysink, & Renkl, 2009). Instructors who promote self-explanation can require learners to provide written answers (Yeh et al., 2010) or merely use them as scaffolding (Mayer et al., 2013). This study printed out the guiding questions on a sheet of paper and required students to answer each question; the answers were not graded but used as notes when students' completing the posttest.

Some empirical studies revealed positive self-explanation effects (Berthold et al., 2009; Choi, 2000; Chi & Wylie, 2014; Mayer et al., 2003; Schworm & Renkl, 2006). Yeh et al. (2010) found that low prior knowledge level students who received self-explanation questions performed better than those who did not receive in multimedia learning environments. Schworm and Renkl (2006), Mayer et al., (2003) compared participants who received or did not receive self-explanation questions, finding that the participants who received the prompts performed better than those who did not receive the prompts in knowledge transfer tests. The application of self-explanation is an appropriate metacognitive strategy for constructing interactive multimedia learning environments.

Cognitive Load Types and Learners' Prior Knowledge Considerations

The purpose of this study that incorporated segmentation and self-explanation into constructing cognitive interactivity is to help learners involved in video modeling instruction develop evaluative abilities. Paas et al., (2003) contended that learning achievement is "an aspect" (p.64) of cognitive load. Any instructional design imposes cognitive load on learners' working memory, and the cognitive load, in turn, will affect learning achievement. Consequently, cognitive load is a mediator between instructional design and learning achievement (Paas et al., 2003). Thus, when evaluating the effects of segmentation and self-explanation on learning achievement, this study also evaluated the influences of these instructional features on cognitive load.

This study focused on the examination of cognitive load effects regarding intrinsic load, extraneous load, and germane load. As was discussed in previous sections, the adoption of segmentation in video modeling was assumed to help learners with intrinsic load and germane load, and the adoption of self-explanation is assumed to help learners with germane load. Thus, there was a necessity for this study to examine the actual effects of instructional features designed by these two principles on different types of cognitive load.

Moreover, this study considered to partition the influence of learner characteristics, such as prior knowledge, to better understand the effects of video instruction on cognitive load and learning achievement. Prior knowledge base is one of the most critical learner traits that affect effects of instructions (Kalyuga, 2005; Yeh et al., 2010). Leppink et al. (2013) stated, “The extent to which instructional features contribute to EL [extraneous load] or GL [germane load] may depend on the individual learner and the extent to which the individual learner experiences IL [intrinsic load]” (p. 1058). It is possible that the self-explanation questions may be associated with germane load for some learners but with extraneous load or other learners in this study. Thus, it was necessary for this study to consider the influence of learners’ prior knowledge base. A prevalent practice dealing with prior knowledge in many social science fields is a median split that turns a continuous variable into a categorical one (Grace-Martin, 2018). However, a median split could result in the loss of power (Aiken, West & Reno, 1991) and makes the study harder to find the real effects (Grace-Martin, 2018). Thus, this study eliminated the influence of prior knowledge levels by adding the variable as a covariate during analysis.

The Significance of the Study

There would be two outcomes anticipated from this study. First, this study explored a research idea that incorporates the concept of cognitive interactivity as a framework for the construction of interactive learning environments to achieve higher-level learning outcomes of video modeling of technology integration. Although cognitive interactivity has been studied and discussed throughout literature about multimedia learning, applying the concept into the instructional design is not listed as an approach for developing pre-service teachers’ technology integration knowledge and skills by Ottenbreit-Leftwich et al. (2010). The construction of cognitive interactivity drew up two multimedia learning design principles— segmentation and self-explanation. The findings of this study added to the body of literature that seeks effective instruction to improve teaching technology integration using video modeling approaches.

Second, this study explored a new instructional design by combining segmentation and self-explanation principles into video instruction to realize higher-level learning outcomes (i.e., developing students evaluation abilities). Previous studies regarding multimedia learning adopted either segmentation or self-explanation alone, but there is a dearth of research that explores the combined effects of the two multimedia learning principles. Combining these two design principles is proposed because the learners' active processing will put them in conversation with each other while viewing and making sense of the video. The findings of this study were beneficial for expanding the research scope of multimedia learning and contributed to online learning regarding effectively using video tutorials to conduct instruction. Guided by this goal, the researcher administered video modeling instructions on a website that was similar to an online learning setting.

Research Questions

This study incorporated two multimedia learning principles—segmentation and self-explanation—into the design of video modeling instruction for constructing cognitive interactivity. The design effects were examined by two measures: cognitive load and learning achievement. Also, this study would like to collect students' perspectives of the video instruction drawing upon the two design principles. Therefore, the following questions were used to guide this study:

1. What are the effects of segmentation and self-explanation designs on learners' cognitive load when incorporating prior knowledge into consideration?
2. What are the effects of segmentation and self-explanation designs on learners' achievement when incorporating prior knowledge into consideration?
3. How does learning achievement relate to students' prior knowledge and cognitive load?

4. What are students’ perspectives of segmentation and self-explanation designs used in the study?

CHAPTER 2

REVIEW OF RELATED LITERATURE

This chapter provided an overview of cognitive interactivity in video modeling. Constructing cognitive interactivity aimed at helping preservice teachers' developing professional knowledge as well as an ability to evaluate technology integration in a video modeling instruction. Cognitive interactivity and two multimedia learning design principles—segmentation and self-explanation—were presented to examine the impact of cognitive interactivity design on facilitating deep, generative learning during video modeling. This chapter also presented relevant cognitive theories that provide not only the foundation for constructing cognitive interactivity but also insights for evaluating the construction effects. This chapter concluded with suggesting ideas of how to measure the design of segmentation and self-explanation, drawing upon theoretical and empirical studies in the area of cognitive load measurement.

Video Modeling

Video modeling is a format of observational learning in which students learn desired behaviors by viewing a filmed or videotaped demonstration. Bandura's Social Learning Theory (1978) underscores that a large proportion of what we learn and how we behave is primarily learned by observing and imitating others. Observational learning can help an individual develop a cognitive image of how to perform a certain behavior (Bandura, 1978; Ottenbreit-Leftwich, GlazewsKi, & Newby, 2010). Modeling describes the process by which a model demonstrates a behavior that can be imitated (Corbett & Abdullah, 2005). The term "model" refers to “any representation of a pattern for behaving” (Lefrancois, 1982, p.291). Bandura and Walters (1963) define two types of modeling: real life modeling and symbolic modeling, which is further divided into verbal and pictorial modeling. As media technologies advance, however, new terms become necessary to describe the new types of modeling suitable for the current era. West and Graham (2007) propose three new terms for modeling types—live modeling (e.g., face-to-face modeling), text-based modeling, and video modeling—based on the medium employed for conveying models. Video modeling refers the use of multimedia technology to record and present the chosen models.

Video modeling has some advantages in comparison to live modeling and text-based modeling. First, video models can be reused and shared across spatiotemporal limits, while both live modeling and text-based modeling are restricted in terms of accessibility for potential audiences. Live modeling cannot be shared with those who are not present at the time and place of demonstration, and text-based modeling cannot be shared as widely and efficiently as video modeling. Second, video modeling provides multiple representations of the same information (Hubscher-Younger & Narayanan, 2008). Although text, graphics, and illustrations are often used together in text-based modeling, these media remain static, meaning they are less engaging than the dynamic, interactive scenes created in video modeling. Text-based modeling cannot use appropriate vocal effects, such as dialogue or voiceover, to facilitate better understanding of the models. Third, video modeling can fluently present processes that occur over time to help the audience develop a comprehensive perspective about the model and its context; for example, a video model can vividly show processes of an activity lasting for a long time in just a few minutes using video editing technology and skills; for example, using sequencing can organize the shortened clips in a logical and clear way for storytelling. It is difficult for text-based modeling to realize dynamic presentation effects that video modeling creates. Fourth, the advance of multimedia technologies allows appropriate interventions to be taken in the video to create interactivity between video models and learners in order to facilitate active, deep learning. A video composed of the content of different topics can be split into segments, and each segment focuses on a single topic. The development of multimedia technologies constantly provides chances to create interactions between learners and the media. Guided by appropriate cognitive learning theories or guidelines, the interactivity can play a powerful role in facilitating deep learning.

Video modeling is a well-validated instructional approach widely adopted in a variety of educational settings. Video modeling generally involves students viewing a video that demonstrates the targeted behavior or skill (Corbett & Abdullah, 2005). New terminology for video modeling has emerged based on practical applications, such as video case study (Beck, King, & Marshall, 2002; Friel & Carboni, 2000), web-based video study (Dieker, et al., 2009), video-based approach (Blomberg, Stürmer, & Sidel, 2011), or vignette (Ottenbreit-Leftwich, Glazewski, & Newby, 2010). Despite the different terms, all of these approaches use videos as an instructional tool to teach a certain professional knowledge, expertise, or skill, such as technology integration. This study defines video modeling as using real-life exemplary teaching practices recorded as a video to model a specific knowledge and skill.

Technology Integration

Realizing the prominent role that information and computer technologies (ICTs) play in today's society, educational institutions, ranging from kindergartens to universities, have been working diligently to encourage technology integration in classrooms on a daily basis. Technology integration refers to the use of technology tools in education in order to allow students to apply ICTs and skills to conduct meaningful learning (Howland, Jonassen, & Marra, 2012). Technology integration focuses on ways to facilitate students' mastery of specific learning outcomes or an ability to solve authentic problems through participating in appropriate learning activities and using ICTs (Brantley-Dias & Ertmer, 2013; Voogt, et al., 2013). Thus, technology integration is labelled as *ICT-related PCK* (Pedagogical Content Knowledge) (Angeli & Valanides, 2005), *technology-enhanced PCK* (Neiss, 2005, p. 509), or *TPACK* (Technology pedagogical content knowledge) (Koehler & Mishra, 2009). Pedagogical content knowledge was first proposed by Shulman (1986) who intended to "draw attention to the importance of both content knowledge and pedagogical knowledge in order to illustrate how intertwined these two types of knowledge were" (Brantley-Dias & Ertmer, 2013, p.46). Technology integration re-conceptualizes PCK by including technology on the instructional tools list of PCK (Brantley-Dias & Ertmer, 2013; Cox & Graham, 2009). Effective technology integration implies the consideration of the inseparable relationship among content, pedagogy, and technology and the role each element plays in teaching practices (Ertmer et al., 2012; Howland et al., 2012). Therefore, developing learners' professional knowledge of technology integration should include identifying the role of technology for designing and implementing effective technology integration.

Effective technology integration enables students to learn with technology, rather than from technology (Howland et al., 2012). Technologies are not vehicles for conveying knowledge from teachers to students because technologies are more than hardware but not conveyors, either (Howland et al., 2012). The use of technologies is to create supportive learning environments and develop meaningful learning activities that engage students in active, constructive, international, authentic, and cooperative learning processes (Howland, et al., 2012).

Technologies function as intellectual tool kits supporting students' productive thinking, meaning making, and problem-solving (Howland et al., 2012). Effective technology integration turns technology into the intellectual partner of the student who uses it.

Effective technology integration defines the roles of teachers and students in learning differently from the traditional teacher-centered educational form. Teachers in effective technology integration should not work as knowledge disseminators but as learning facilitators who identify appropriate technologies based on the content and pedagogical needs and support students to develop necessary knowledge and skills for solving problems. Students are not passive knowledge receivers, but act as knowledge creators who collaborate with their teachers or peers and use technologies to study and solve problems. Therefore, meaningful learning with technology describes teaching practices that use technology to engage students and facilitate students to actively participate in learning and inquiry.

However, there are various barriers impacting teachers' technology integration in the classroom. Ertmer (1999) distinguished two types of barriers: first-order barriers include external resources (e.g., hardware and software) to which teachers have access; second-order barriers are associated with teachers' belief in, confidence in and perceived value of technology integration, as well as the mastery of professional knowledge and skills regarding technology integration (Ertmer et al., 2012). Based on the analysis of 48 empirical studies regarding technology integration, Hew and Brush (2007) identified the three most frequently reported barriers impacting effective technology integration: (1) resources (reported in 43% of studies), (2) teachers' knowledge and skills (reported in 43% of studies), and (3) teachers' attitude and beliefs (reported in 43% of studies). Therefore, the lack professional knowledge and skill has been identified as a critical obstacle impacting effective technology integration.

Effective integration of technology into the classroom can be affected by insufficient knowledge. Although today's pre-service teachers may be fairly fluent in technological literacy, they have limited knowledge about how to use technology to facilitate teaching and learning (Ertmer & Ottenbreit-Leftwich, 2010). Lim and Chan (2007) observed that many pre-service teachers and beginning teachers were not ready to administer learner-centered use of technology. Lee and Kim (2012) noticed that pre-service teachers experienced difficulties in precisely and critically analyzing and evaluating technology integration examples because of not having sufficient pedagogical knowledge regarding technology integration. Teachers who have a limited knowledge of technology integration often encounter many obstacles in integrating technology into the classroom (Ertmer, 1999; Bai & Ertmer, 2008), and such a technology integration practice may negatively affect teachers' conceptions, confidence, or perceived usefulness of integrating technology in the classroom. Teachers' knowledge is one literally identified key variable that can facilitate teacher change in technology integration (Ertmer & Ottenbreit-Leftwich, 2010). According to Cennamo, Ross, and Ertmer (2010), teachers who can design and implement effective technology integration need knowledge that enables them to:

- "Identify the most appropriate ICT resources to support specific curricular goals.
- Specify how the tools will be used to help students meet and demonstrate those goals.
- Enable students to use appropriate technologies in all phases of the learning process including exploration, analysis, and production.
- Select and use appropriate technologies to address needs, solve problems, and resolve issues related to their own professional practice and growth" (p.260).

Teacher education programs should challenge their participants to adopt a new definition of student-centered technology integration. "Traditional perceptions of what teaching, learning, and knowledge should look like are major limiting factors to integrating technology" (Ritchie & Wiburg, 1994, p.152). This definition should help pre-service teachers identify correct roles of students, technologies, and teachers in student-centered use of technology. In order to help pre-service teachers develop such knowledge, one of the most powerful strategies is to provide them with opportunities to observe exemplary examples and models (Albion, 2003; Ertmer, 2005, 2010; Zhao & Cziko, 2001). Observing exemplary technology integration practice not only informs pre-service teachers of effective strategies but also facilitates their self-reflection on personal knowledge and skills.

Video Modeling of Technology Integration

Video modeling of technology integration refers to providing learners with vicarious learning experiences by having learners observe exemplary examples of technology integration via such media as television or the internet. Video modeling has assumed an increasingly prominent role in teacher education (Star & Strickland, 2007) and is a "viable mean for increasing capacity for technology integration" (Ertmer et al. 2003, p.111). Given that some faculty or tutors may encounter various difficulties in demonstrating live modeling of technology integration, video modeling provides a solution to address these limitations (Brzycki & Dudt, 2005; Ottenbreit-Leftwich et al., 2010; West & Graham, 2007). Observing real life, "evidence-based" (Dieker et al., 2009, p. 194) technology practices can not only improve pre-service teachers' relevant perspectives and knowledge (Ottenbreit-Leftwich et al., 2010) but also bridge the gap between academic preparation and practice (Beck et al., 2002; Dieker, et al., 2009; Van den Berg, Jansen, & Blijleven, 2004; White & Geer, 2013). Affordance has led video modeling to be widely adopted into teacher education programs.

Video modeling can be applied in different ways to develop pre-service teachers' professional knowledge regarding technology integration comprehensively. The learning environments where instructors use video modeling as an instructional approach can be either authentic classrooms or online learning or incorporated in parts of methods courses. The instructional goals of using video modeling in teaching can be aimed at developing pre-services' observation skills and evaluation abilities, improving their beliefs and confidence regarding technology integration, or adding more methods or strategies to pre-service teachers' teaching toolkits (Ertmer & Ottenbreit-Leftwich, 2010; Ottenbreit-Leftwich et al., 2010). Video modeling is a viable instructional approach for learning technology integration in a vicarious way.

Web 2.0 technologies provide easy and free ways to share and gain access to a wide range of technology integration practices. Many institutions and individuals share their recordings of technology integration practices on these social channels such as YouTube and Vimeo. Many educational institutions share free vignettes on technology integration on their institutional websites (Ottenbreit-Leftwich et al., 2010) such as Arizona K12 center, Florida Center for Technology Integration, or Teaching Channel. These free web-based technology integration resources have been vital in facilitating the adoption of video modeling in different technology integration programs.

Video modeling holds substantial promises for enhancing pre-service teachers' technology integration knowledge and skills. Video modeling can help pre-service teachers discriminate the quality of video models. However, pre-service teachers have been found to struggle with evaluating the video content; for example, Dieker et al. (2009) found that pre-service teachers could not provide useful information to synthesize knowledge used in the observed models; Lee and Kim (2014) found that pre-service teachers experienced difficulty with critical analyzing the necessity of applying a technology to the specific content. The current use of video modeling could not support the kinds of instruction believed to be most powerful (Ertmer & Ottenbreit-Leftwich, 2010) and “numerous questions remain” (Dieker et al., 2009, p.194). The most typical issues regarding the current use of video modeling include that students are often observed as passive viewers (Choi, 2014; Hassanabadi et al., 2011; Yeh, Chen, Hung, & Hwang, 2010), and they do not know what to look for while viewing a video model (Kurz & Batarelo, 2010); sometimes the content of video models is so intensive that makes learners feel overwhelmed (Sweller, Ayres & Kalyuga, 2011). Kurz and Batarelo (2010) investigated pre-service teachers’ perspectives and experiences regarding learning technology integration through video modeling, and they found that pre-service teachers would like constructive features to be incorporated into video modeling for supporting their successful learning. These observations and findings in empirical studies propose a need to construct cognitive interactivity for improving learning experiences and outcomes with video modeling.

Video modeling, like other forms of multimedia learning, has infinite potential to offer learners interactive learning experiences. Video modeling presents information with combinations of text, images, and narrations that make video modeling some advantages to realize a better learning than learning from a single medium (Clark & Mayer, 2011). However, to maximize the benefit from multimodal presentations, learners must actively identify relationships between the presented information as well as organize and integrate the information into a coherent structure (Wylie & Chi, 2014; Mayer, 2014). Learning in video modeling is potentially very effective, but only if learners engaging in a cognitively demanding task can get necessary support that enables their learning not to be impacted by some essential barriers; for example, learning materials are too complicated and integrate information across different sources, or students do not have the control over the learning pace. Generative learning is underpinned by students' use of appropriate cognitive or metacognitive strategies that can be embedded in the instructional design (Jonassen, 1988). There is a necessity to introduce a cognitive or metacognitive approach to support learning in video modeling.

Cognitive Interactivity

The concept of cognitive interactivity provides a framework to explain how mental interactions between learners and content mediate learners' cognitive processing of learning materials. Cognitive interactivity refers to mental interactions between learners' internal representations such as propositions or schemas, and external representations such as video footage, of to-be-learned when a learner is working on a cognitive task. Different external representation concerned different cognitive properties that can be either challenging or satisfying learners' cognitive processing capacity (Aldrich et al., 1998; Kozma, 1991; Moreno & Mayer, 2007). According to Rogers and Scaife (1999), cognitive interactivity is concerned with how a learner uses and adapts new information and organizes and integrates associated information into a new coherent representation. The construction of cognitive interactivity embraces a series of cognitive progresses including searching, selecting, organizing, and integrating information to solve a problem or activity (Aldrich et al., 1998; Mayer & Moreno, 2003). Deep conceptual processing and integration of the presented materials can be facilitated by appropriate instructional scaffoldings that actively involve learners with the learning materials.

There is a necessity to distinguish cognitive interactivity and functional interactivity because the two distinct types of interactivity may create confusion when considering effective instructional strategies. Functional interactivity defines a response-based interaction model, focusing more on providing functional affordances at the program interface (Kennedy, 2004; Sundar, Kalyanaraman, & Brown, 2003). Functional affordances can range from low-involvement controlling of pace of an instructional video to high-involvement controlling simulation, such as changing the course of events (Kristof and Saturn, 1995). The design of functional interactivity aims to create physical interactions between learners and elements of the interface for more fun or quicker physical responses. However, coupling multimedia with a variety of functional affordances at the interface level does not mean that video modeling instruction can automatically facilitate generative learning (Reeves, 1993), as it is the learner's cognition rather than the technology itself that mediates the acquisition of knowledge (Jonassen, 1988). Reeves (1993) pointed out, "multimedia without interpretive acts of learners is only a collection of textual, graphical and audio elements" (p.80). The essential difference between cognitive interactivity and functional interactivity is whether or not the interactivity can meaningfully, conceptually involve learners in generative processing of the presented information for constructing a new, coherent mental representation. The construction of cognitive interactivity necessitates the consideration of relevant cognitive load theories in multimedia learning.

The Cognitive Load Theories in Multimedia Learning

Video modeling is not merely learning from multimedia but characterized as the active cognitive processing of visual and verbal information (Moreno & Mayer, 2007). Different instructions produce different types of cognitive processing that imposes different types of cognitive demands on the human's cognitive system. Within cognition psychology, there are a couple of cognitive load theories that contribute to the design of cognitive interactivity. The cognitive theory of multimedia learning and the cognitive load theory were explored here because they are also theoretical foundations for understanding learners' cognitive systems during video modeling and provide critical guidelines for evaluating the design effects of cognitive interactivity in video modeling.

Cognitive Theories of Multimedia Learning

Video modeling is a type of multimedia learning that presents learning information in a video format. Based on the three assumptions described in a previous section on conceptual framework, Mayer (2005) developed the Cognitive Theory of Multimedia Learning that describes how the human cognitive system work in a multimedia learning setting (Figure 2).

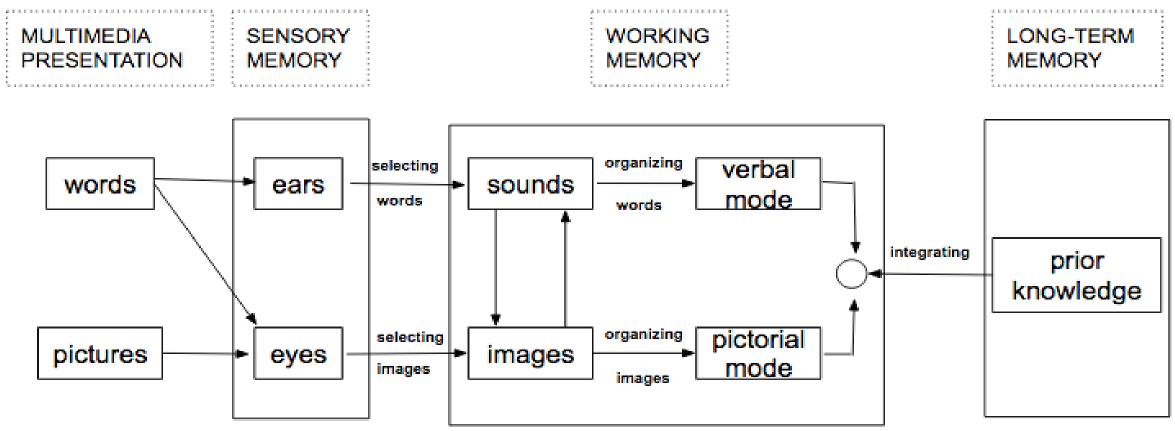


Figure 2. Cognitive theory of multimedia learning. Reprinted from Nine ways to reduce cognitive load in multimedia learning (p.44) by Mayer, R. and Moreno, R. (2003). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

As is shown in Figure 2, students build mental representations from words and images presented to them (Mayer, 2003). Cognitive processing, in multimedia learning environments, is composed of a series of cognitive processes: 1) selecting relevant words and images from instructional message, 2) organizing the selected information into logical, coherent representations, 3) integrating the organized representations and relevant prior knowledge stored in the long-term memory into a new coherent representation (Mayer et al., 2003; Mayer, 2014). However, mere exposure to multimedia materials does not guarantee learners to automatically process the information across knowledge sources (Wylie & Chi, 2014). Students in a dynamic multimedia environment have difficulty interpreting the semantic knowledge of the intensive, multiple representations to-be-learned without any metacognitive scaffolding (Kalyuga, 2005; Yeh et al., 2010). Students need to be prompted to select, organize, and integrate information during viewing a video and encouraged to reflect during learning (Moreno & Mayer, 2007; Wylie & Chi, 2014). Thus, multimedia learning indicates both promises and challenges for multimedia instructional design (Mayer, 2013).

One promise of multimedia learning is that multiple sources of information are helpful to engage learners into the active, constructive, or generative learning process that leads to understanding and problem-solving (Mayer, 2013; Wylie & Chi, 2014). Another promise is that “multimedia instruction messages can be designed in ways that are consistent with how people learn, and thus can serve as aids to human learning” (Mayer, 2003, p.127). One challenge of instructional design is to prime and guide learners to conduct active, generative cognitive processing to construct meaningful, coherent mental representations (Mayer, 2013). Another challenge is to avoid cognitive overload; for example, learner’s intended cognitive capacity exceeds the learner’s available cognitive capacity. Thus, this study explored the cognitive load theory and the three types of cognitive load to interpret the promise and challenges of multimedia learning.

Cognitive Load Theory

Cognitive load theory (CLT) is an instructional theory based on our knowledge of the cognitive architecture that treats long-term memory as the central structure of the system. Long-term memory has an infinite capacity which means that long-term memory can store virtually unlimited, permanent information (Sweller, 2011). Another component of the cognitive architecture is working memory. Because the capacity of working memory is limited, it can temporarily hold and process limited information at one time (Paas et al., 2003). "Central to CLT is the notion that working memory and its limitations should be a major consideration when designing instruction" (Pass, Renkl, & Sweller, 2003, p. 64), thus the challenging of working within the CLT framework is designing innovative instructional methods that can efficiently use the working memory capacity and instructional control cognitive load for attaining knowledge transfer (Pass et al., 2003). Although the challenge is significant, many CLT-based instructions have been proven successful (Pass et al., 2003).

Cognitive load theory recognizes the concept of cognitive load as a crucial factor for learning a complex cognitive task. Cognitive load is defined as a multidimensional construct representing the load that working on a cognitive task imposes on a learner's cognitive system (Paas, Van Merrienboer, & Adam, 1994; Paas et al., 2003; Sweller, 2011). The construct distinguishes three different types of cognitive load: intrinsic load (IL), extraneous load (EL), and germane load (GL) (Paas et al. 2003). These three different types of cognitive load are considered as the major factors and determinants of successful instructional interventions because the construct has "a causal dimension reflecting the interactions between task and learner characteristics" (Paas et al., 2003, p.64) and an assessment dimension reflecting the learners' performance at a specific task (Paas et al., 1994; Paas et al., 2003; Leppink, et al., 2013). Defining and distinguishing the three different types of cognitive load is critical for the multimedia instructional design and design evaluation.

Intrinsic load. Intrinsic load refers to the load resulting from the inherent complexity of learning materials or a learning task. Intrinsic is fixed and innate to the task for a given task and given learner knowledge levels, and it "cannot be altered except by changing the nature of what is learned or by the act of learning itself" (Sweller, 2010, p. 124). Sweller (1994, 2010, 2011) related inherent complexity to element interactivity. An element refers to information that needs to learn for completing a task; for example, concepts or procedures (Sweller, 1994, 2010, 2011). A low-complexity learning material involves few interacting information (Sweller, 2010); for example, memorizing the categories of correct roles that students should play in a meaningful technology integration learning activity. A high-complexity learning material involves much interacting information (Sweller, 2010), requiring learners to relate and assimilate the information simultaneously during learning (Sweller, 2010). For example, in the video used in this study, administers and researchers introduced theories of meaningful technology integration and the concepts of students' roles in a meaningful technology integration practice, and several teachers demonstrated and explained their technology integration practices; students had to integrate all of the information they heard with the specific learning context and classroom interactions that they viewed when evaluating a teaching practice. "The more elements that interact, the heavier the working memory load." (Sweller, 2010, p. 124). The level of element interactivity is the determinant for measuring the intrinsic load of a particular task.

Extraneous load. Extraneous load refers to the extra load beyond intrinsic load and results from inappropriate, poor instructions that require learners to process irrelevant elements of information and interfere with learning and occupying the working memory capacity (Sweller, 2011). Paas et al. (2003) contend that "failure of learning and performing complex cognitive tasks can normally be associated with the task demands that exceed the available cognitive capacity, the inadequate allocation of cognitive resources, or both." (p. 64), so reducing extraneous load is the primary concern of cognitive load theory (Sweller, 2010) and "should be always reduced with no conditions under which it should be increased." (Sweller, 2011, p. 63).

Sweller (2011) contended that element interactivity is the primary source of working memory load underlying both intrinsic and extraneous cognitive load. Because the level of element interactivity is also the determinant of the level of extraneous load (Sweller, 2010; Beckmann, 2010), it is necessary to distinguish between extraneous load and intrinsic load.

There are two arguments proposed to distinguish intrinsic load from extraneous load. According to Sweller (2010), the distinguishing can be based on what needs to be learned; for example, providing that the goal of video learning is to comprehend knowledge and information mentioned in the dialogues in the video, if jargons are used in self-explanation question and students do not understand them, then the jargons may constitute extraneous load; alternatively, if the jargons are used in the dialogues in video and students do not understand them, the jargons are intrinsic to the task. Second, it is according to Beckmann (2010), the distinguishing can be based on the way to alter element interactivity: if element interactivity can only be altered by changing the nature and goals of learning, the load is intrinsic; if element interactivity can be reduced without changing the nature and goals of learning, then the load is extraneous. Identifying unnecessary and interrupting interacting elements is the key to distinguishing intrinsic and extraneous load.

Germane load. Germane load is another type of extra load beyond intrinsic load, and it is placed on working memory during schema formation and automation (Pass et al., 2003; Sweller, 2010, 2011). Because germane load is “concerned only with learner chrematistics” (Sweller, 2011, p.126), it refers to “the working memory resources that the learner devotes to dealing with the intrinsic cognitive load associated with information” (Sweller, 2011, p. 126). Germane load is facilitated by effective instructional design that contributes to the construction and automation of schemas in the long-term memory (Paas et al., 2003; Sweller, 2011).

Facilitating germane load is a prime goal of instruction (Sweller, Van Merrienboer, & Paas, 1998).

Germane load is concerned only with learner characteristics that determine the working memory resources that learners devote to dealing with the intrinsic load associated with the learning materials. However, intrinsic load and extraneous load are both concerned with the learning characteristics. Unlike intrinsic load and extraneous, germane load does not "constitute an independent source of working memory load [...and] merely refers to the working memory resources devoted to handling intrinsic cognitive load." (Sweller, 2010, p. 126). Germane load and extraneous load are complementary, and the increase in germane load means that less working memory resources are being used to deal with element activity associated with extraneous load (Sweller, 2010). Germane load is purely a well-organized function of the working memory resources that allow working memory resources to deal primarily with the interacting elements that determine intrinsic load (Sweller, 2010). Many efforts have been devoted to facilitating germane load in multimedia learning, and segmentation and self-explanation are two of the efforts.

Design Principles and Guidelines for Constructing Cognitive Interactivity

This study designed and developed a video modeling instruction activity in which pre-service teachers learn professional knowledge and skills related to technology integration. The activity was grounded in observational learning and cognitive interactivity frameworks. Evidence from relevant literature led to the following design principles of video segmentation and self-explanation, and their respective guidelines for constructing effective cognitive interactions during video modeling.

Principle #1: Segmentation

The literature on multimedia learning highlights the importance of segmentation for improving deep and generative learning. The segmentation principle is based on the premise that having learners view a video from the beginning to the end could exceed the learners' cognitive capacity and result in cognitive overload if a video tutorial contains a large amount of information and information interactions (Mayer & Chandler, 2001; Clark et al., 2011). One design solution to avoid essential cognitive load is segmentation (Doolittle et al., 2015; Mayer & Chandler, 2001). The operation of segmentation is to split a continuous video instruction into a set of smaller, meaningful, and manageable segments (Koprinska & Carrato, 2001; Mayer & Moreno, 2003), which is presented one at a time (Mayer et al., 2001; Doolittle et al., 2015; Clark et al., 2011). Students then view a video instruction in discrete segments rather than as one continuous presentation (Hassanabadi, Robatjazi, & Savoji, 2011). Students can benefit from viewing segmented videos when the video is complex in content, presented at a fast pace, or playtime is long.

Video segmentation can be operated using two methods: (1) student-manipulated segmentation that allows students to make a decision over video segmenting by clicking on a play/pause button during video playing, and (2) system-manipulated segmentation that is conducted by instructors or subject matter experts' segmentation of a whole video into smaller parts based on a certain rationale (e.g., different scenes). According to Fiorella and Mayer (2018), the challenge with the student- manipulated segmentation method is that students' control over the video pacing cannot be as optimal for learning as the system-manipulated method; this is because students, especially novice learners, "may not have the knowledge or metacognitive skills to know when they should pause the video" (p.466). In comparison to student-paced segmentation, the system-manipulated segmentation method allows students to focus on viewing and making sense of the presented information of each video segment and not worry about when to pause. Also, system-manipulated segmentation allows students to fully process finite chunks of information before moving to the next segment (Lusk et al., 2009; Doolittle et al. 2015). Thus, this study used the system-manipulated segmentation method that was operated by the researcher.

Segmentation effects on cognitive load. Fiorella and Mayer (2018), Mayer and Moreno (2003), and Mayer (2014) stated that segmentation was a technique for helping learners manage intrinsic load during learning. Doolittle et al. (2015) found that segmentation designs could avoid intrinsic overload in their study that chucking a 9-minute historical instruction video into 7, 14 and 28 segments respectively. Splitting a continuous video into discrete segments that are viewed one by one addresses the level of element interactivity. Moreover, segmentation addresses germane load because system-manipulated segments allow learners to view the segments and understand sufficiently before proceeding to the next segment. Doolittle et al. (2015) found that students saw the value in segmentation as an instructional strategy for enhancing learning. Hasler et al. (2007) found that segmentation resulted in reduced cognitive load.

Segmentation effects on learning achievement. The segmentation principle has been widely adopted for designing interactive multimedia learning environments. Though research on the effects of segmentation has not been conclusive (Doolittle et al., 2015), many empirical studies that adopted segmentation have reported improvements of learners' performance in either lower-level or higher-level learning, including recall tests (Doolittle et al., 2015; Hassanabadi et al., 2011) and knowledge transfer and problem-solving tests (Doolittle et al., 2015; Mayer et al., 2001). Segmented video tutorials have been found to do better in terms of reducing cognitive load and promoting engagement and learning than non-segmented video tutorials (Guo, Kim & Rubin, 2014; Hassanabadi et al., 2011; Kim et al., 2014; Doolittle et al., 2015). These findings provide evidence that segmentation is a suitable design principle for constructing cognitive interactivity in video modeling instruction.

Design guidelines. There are multiple factors to be considered when designing meaningful and manageable segments. First is to identify an appropriate approach for segmenting a video. Video segmentation generally involves the partitioning of a video into its constituent parts, such as instructional scenes. Instructional scenes are analogous to chapters of a book, and a scene comprises a series of consecutive shots grouped together because they were shot in the same location or share thematic content (Carlson, Gray, Kulkarni, & Taylor, 2018; Fiorella & Mayer, 2018). Therefore, the seven-minutes-and-forty-seconds instructional video was chucked into six segments, and each segment addressed a different instructional scene. Doolittle et al. (2015) investigated learner dispositions towards segmentation in their study that chucked a nine-minute historical instructional video into seven, 14, and 28 segments based on "where in the tutorial it made conceptual sense to insert a 'segment control point'" (p. 1336). Doolittle et al. (2015) found that learner dispositions to the design of one segment, seven segments, and 14 segments were very close, except perceiving the design of 28 segments more negatively. Thus, the study decided to segment the video into six segments based on instructional scene change in the video.

The second factor is to add video segment subheadings to each segment. Subheadings can not only help learners to quickly figure out the video content to-be-viewed but also provide learners observation guides that can "support pre-service teachers in developing an ability to notice and interpret aspects of classroom practice that are important to perform pedagogy." (Van

Es & Sherin, 2002, p.8). According to Star and Strickland (2008), pre-service teachers do not have well-developed skills for observing other teachers' classroom when they initially begin teacher training, so improving their observational abilities should be an explicit focus of initial teacher preparation course by providing "opportunities and structures within which teachers can develop their ability to notice" (Sherin & van Es, 2005, p. 489). Thus, the features that are expected to be noticed by pre-service teachers can be incorporated into the metadata. The third factor is the acquisition of perspectives from representative members of the intended audience or subject matter experts. Operating video segmentation is highly subjective, so it requires comprehensive perspectives to decide on how to index a video (Carlson et al., 2018). Based on the above-discussions, three design guidelines are proposed to implement segmentation in this study:

Guideline 1: Create system-manipulated video segments

Guideline 2: Segment a video based on the change of instructional scenes

Guideline 3: Add a subheading to each video segment

Principle # 2: Self-explanation

Cognitive functions of self-explanation prompts imply powerful, robust cognitive functions for improving deep and generative learning in video modeling instruction. Wylie and Chi (2014) identify several features of prompted self-explanation that can help facilitate cognitive interactivity. First, if prompts can orient students' attention to critical information, they will engage students cognitively and meaningfully with learning materials (Wylie & Chi, 2014; Yeh et al., 2010). Second, prompted self-explanation is expected to help students fill the information gaps between the learning materials and their existing schema, recognize conflicts of understanding, and amend flaws in the schema (Wylie & Chi, 2014; Yeh et al., 2010). Third, an essential indicator for the success of using prompted self-explanation in multimedia learning environments lies in whether or not self-explanations can direct and encourage students to make connections across knowledge sources. These features are helpful for designing self-explaining prompts for video modeling instruction.

Selecting appropriate prompts is critical for optimizing the effects of self-explanation. A variety of formats of self-explanation prompts have been proposed, and Wylie and Chi (2014) organize these prompts along a continuum: at one end of the continuum are open-ended self-explanation prompts, and at the other end are menu-based self-explanation (Figure 3). Different forms of self-explanation imply different advantages to multimedia learning. As shown in Table 3, prompted self-explanation can be designed in a variety of ways and across a number of instructional resources. Nonetheless, all forms of self-explanation encourage students to think deeply about learning materials to-be-learned and may lead to improved learning over on-self-explanation controls (Wylie & Chi, 2014). The variety of self-explanation prompt forms provide multiple options for constructing cognitive interactivity of video modeling instruction.

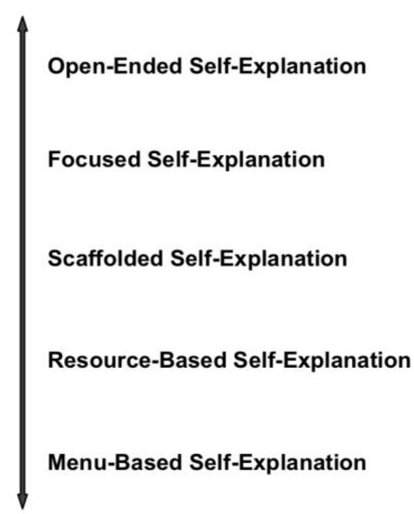


Figure 3.Continuum of different forms of self-explanations. Reprinted from the self-explanation principle in multimedia learning (p.420) by Wylie, R. & Chi, M.T.H. (2014). New York, NY: Cambridge University Press.

Table 3.

Summary of Different Forms of Self-explanation Prompts

Self-explanation Prompt Formats	Descriptions	Advantages
Open-ended self-explanation	Encourage students to integrate across knowledge resources but allow students to generate their explanation in the absence of any limits or expectations (Chi et al. 1989, 1994).	Students feel free to explain their mental model and make connections where they see fit; students are not influenced by preconceived ideas about what may be challenging or where knowledge gasp may exit (Wylie & Chi, 2014).
Focused self-explanation	Allow students to generate their explanation in the absence of any limits or expectations but provide more explicit instructions regarding what the content of the self-explanation should include (Gadgil, Nokes-Malach, & Chi, 2012).	Direct student explanations in a specific way (Wylie & Chi, 2014).
Scaffolded self-explanation	Utilize a cloze or fill-in-the-blank approach with students filling in missing parts to complete the explanation or justification (Berthold, et al., 2009).	Benefit novice learners lacking sufficient prior knowledge to generate open-ended explanations on their own (Wylie & Chi, 2014).
Resource-based self-explanation	Use a provided glossary as a reference to look up explanations and thus turn the explanation step into a recognition rather than recall problem (Aleven & Koedinger, 2002).	Reduce the number of incorrect self-explanations and provide feedback to students on their explanation choices (Wylie & Chi, 2014)
Menu-based self-explanation	Facilitate deep thinking about learning materials by asking students to select explanation from a provided menu (Berthold et al., 2009)	Reduce the number of incorrect self-explanations and provide feedback to students on their explanation choices (Wylie & Chi, 2014).

Adapted from *the self-explanation principle in multimedia learning* (pp.421- 422), by Wylie, R. & Chi, M.T.H. (2014). New York, NY: Cambridge University Press.

Self-explanation effects on cognitive load. Sweller (2010) stated that self-explanation instruction could facilitate germane load. Self-explanation instruction requires learners to self-explain concepts during learning, and the act of self-explanation directs working memory resources to deal with relevant interacting elements of the learning material (intrinsic load) rather than engaging learners into activities unrelated to the relevant interacting elements (extraneous load). Sweller (2011) argued that self-explanation instruction could direct learners to use cognitive processes that encourage them to eliminate activities extraneous to learning by engaging in activities conducive to learning. Self-explanation instruction could reduce extraneous cognitive load and facilitate germane load.

Segmentation effects on learning achievement. Empirical studies have found evidence for positive effects of self-explanation prompts on learning. Several empirical studies have shown that students who are prompted to frequently self-explain the learning material do better in conceptual understanding (Chi & Wylie, 2014; Kwon, Kumalasari, & Howland, 2011) and outperform in knowledge application tests than those who are not (Chi & Wylie, 2014; Mayer et al., 2003; Yeh et al., 2010). These findings provide evidence that adopting self-explanation in video modeling can develop effective metacognitive strategies that contributes to schema development and automation.

Design guidelines. Although prompting students to self-explain the learning material has been recognized as a useful form of instructional strategy for facilitating cognitive engagement and active learning; multiple indicators need to be considered for the design of self-explanation prompts. These factors include learning achievement and cognitive load demand (Yeh et al., 2010). Learning achievement is a valuable variable to measure learning effectiveness directly and has been widely used in empirical studies. Learning achievement is also valuable to understand the efficiency of a learning process that can help investigate the influence of an instructional strategy or a learning strategy in a comprehensive way. Cognitive load demand is a valuable measure for the efficiency of a learning process (Yeh et al., 2010). Based on the cognitive load theory, effective self-explanation prompts should adequately manage the intrinsic cognitive load of the material to-be-learned and guide learners to efficiently spend their cognitive capacity on generative learning germane to schema development (Yeh et al., 2010). An optimal learning process refers to the highest learning outcome associated with the minimum amount of cognitive load (Salden et al., 2004). Thus, it is meaningful to measure how students respond to self-explanation prompts and whether self-explanation prompts will induce germane cognitive load or extraneous cognitive load (Kalyuga, Chandler, & Sweller, 1999; Yeh et al., 2010). These multiple factors are valuable to measure the effectiveness of constructing cognitive interactivity in video modeling. Based on the above-discussions, three design guidelines are proposed to implement self-explanation in this video modeling (Wylie & Chi, 2014):

1. Direct learners' attention to critical information for interpreting the messages conveyed within a specific instructional scene.
2. Facilitate students to identify and fill in the gaps between the learning materials and their existing schema.
3. Encourage learners to synthesize information when evaluating a teaching practice.

Measurement of Cognitive Load in This Study

Knowing students' cognitive load during learning is meaningful for understanding the effects of an instructional design regarding video modeling. However, measuring cognitive load is one of the biggest, persistent challenges in educational research (Leppink et al., 2013; Mayer et al., 2003). Efforts to measure cognitive load can be categorized into two main respective practice types: one focuses on measuring the overall cognitive load, and the other measures different types of cognitive load separately (Leppink et al., 2013; Paas et al., 1994) because cognitive load is “a multidimensional construct that represents the load that performing a particular task imposes on the cognitive system of a particular learner” (Pass et al., 1994, p.122). Following the instructional design efforts closely, researchers tend to measure intrinsic, extraneous, or germane load separately or any types of cognitive load that they are interested in investigating rather than overall measurement (Ayres, 2006; Paas et al., 2003). Thus, the measurement of cognitive load is related to the researcher’s concerns and interests.

The decision on measurement approaches of cognitive load also needs to account for the advantages and disadvantages of these approaches. There are some disadvantages with the approach of measuring the overall cognitive load. The approach of measuring the overall cognitive load tends to focus on examining the task difficulty rather than mental effort as a significant estimator of cognitive load (Paas et al., 2003). Moreover, the approach of measuring the overall cognitive load does not allow the researcher(s) to conduct a further and detailed investigation of the problem associated with the cognitive load when the study findings did not support the research hypothesis. Yeh et al. (2008) conducted a 3 (research conditions) x 2 (prior knowledge levels) factorial design study to investigate the effects of self-explanation prompts customized for different prior knowledge levels on cognitive load and learning achievement. They developed reasoning-based prompts for lower-prior knowledge (LPK) students and predicting-based prompts for higher-prior knowledge (HPK) students. Yeh et al. (2008) utilized a nine-point cognitive load scale that was modified from the popular scale developed by Paas (1992) and Pass et al. (1994) for assessing an overall cognitive load. Yeh et al. (2008) administered the scale twice after participants had completed two required animations respectively and computed the load scores by averaging the two ratings. Yeh and colleagues found that HPK students who used predicating-based prompts experienced a significantly higher cognitive load than LPK students who used reasoning-based prompts; this finding did not support Yeh et al.'s hypothesis that predicating-based prompts would save cognitive load demand for HPK. However, Yeh et al. did not investigate in depth on the extent to which the predicating-based prompts contribute to extraneous load and whether or not the predicating-based prompts contribute to germane load. Thus, researchers need to measure the different types of cognitive load if they are interested in examining design effects on impacting students' mental efforts in a more detailed way.

Scholarly efforts have been invested in measuring different types of cognitive load and achieved certain accomplishments. Johnson, Ozogult, and Reisslein (2015) used the approach of measuring different types of cognitive load in their study. Johnson et al. conducted a four-condition experiment to examine the effects of two multimedia design principles−visual signaling and animated pedagogical agent−on cognitive load as well as learning achievement on LPK students and HPK students. Based on the 11-points, 10-item Likert-type survey questionnaire developed by Leppink et al. (2013), Johnson et al. developed a five-points, eight-item Likert-type questionnaire to measure the design effects on 'perceived difficulty' (i.e., extraneous load) and germane load separately. Johnson et al. administered the survey once and computed each type of load scores "by averaging the ratings from the respective questions that loaded on these factors" (Johnson et al., 2015, p.105). Johnson et al. found that visual signaling was associated with significantly reduced extraneous load but not with significantly improved germane load. Johnson et al. contended that visual signaling may benefit the information selection phase process based on the perceived difficulty ratings and the relevant hypothesis "the visual signaling would reduce extraneous load associated with the selection phase of CTML [the Cognitive Theory of Multimedia Learning]" (p. 101). Johnson et al. also contended that visual signaling did not benefit the referential connections between verbal information and visual information (i.e., germane load) based on the hypothesis that “the visual signaling techniques make explicit the inter-representation relations, thus supporting the mental integration of multiple representations.” (p.101). Moreover, Johnson et al. did not find any significantly reduced extraneous load and improved germane load with APAs. Examining the different types of cognitive load separately could offer more details to explain hypotheses. By comparing the findings of Yeh et al., the findings of Johnson et al. could examine the effects of instructional design and test hypotheses in a more detailed way. “The measurement could become more precise when using multiple items for each of the separate types of CL [cognitive load]” (Leppink et al., 2013, p. 1059). Measuring the different types of cognitive load leads to a more detailed and precise examination of instructional design efforts.

The tools to measure cognitive load also differ among empirical studies. Using subjective rating scales is one of the tools utilized for measuring cognitive load (Ayres, 2006). The reliability of using subjective rating scales is supported and justified by experimental studies and a pilot study of this study, which revealed that students can reflect on their cognitive processes, assess amount of invested mental effort reliably and unobtrusively, and interpret the different load scales in the way intended by the researchers (Ayres, 2006; Paas et al., 2003; Yeh et al., 2010). Using subjective rating scales is suitable for this study which is interested in knowing students’ feelings and mental efforts experienced for a specific instructional design. Also, the subject rating of mental efforts can complement the objective measures of pretest and posttest included in the study.

Combining the above discussions, this study was interested in investigating the design effects of segmentation and self-explanation on different types of cognitive load. Measuring different types of cognitive load separately could help the researcher better analyze the effects of different instructive methods on attained learning achievement than the measurement of an overall cognitive load. Considering the fact that subjective self-rating scales are easy and feasible to implement in this study and does not intrude on the main instructional task (Mayer & Chandler, 2001), this study used the subjective rating scales that was modified from the verified scales developed by Leppink et al. (2013) for cognitive load measurements.

CHAPTER 3

RESEARCH DESIGN

This study examined the effects of different video modeling instruction methods that adopted segmentation and self-explanation into the instructional design on student cognitive load and learning achievement. This study added students' prior knowledge as the covariate in the data analysis. The design of this study was a four-group pretest-posttest experiment. The researcher randomly assigned participants to one of four research groups. The primary independent variable, video modeling instruction, was a categorical variable. Video modeling instruction was developed by adopting the multimedia design principles of segmentation and self-explanation. Thus, video modeling instruction was administered in four conditions — the control condition and three experimental conditions. The control condition referred to a video modeling instruction adopting neither a segmentation intervention nor a self-explanation intervention. The three experimental conditions referred to a video modeling instruction adopting (a) a segmentation design, or (b) self-explanation design, or (c) the combination of segmentation and self-explanation design (referred to as the combination condition). The dependent variables were students' cognitive load and learning achievement. Cognitive load data were obtained from students' responses in the cognitive load survey, including intrinsic load, extraneous load, germane load, and the total load. Learning achievement data were obtained from students' responses in the posttest, including professional knowledge, evaluation abilities, and overall scores. Prior knowledge data were obtained from students' responses in the pretest. The same pretest, posttest, and cognitive load survey were administered under each of the four conditions. The pretest was administered before video modeling instruction, and the posttest and cognitive load survey were given after video modeling. All documentation for the study was submitted to and approved by the Institutional Review Board (IRB) (see Appendix A).

Participants

The participants were recruited from an interdisciplinary technology integration course offered for pre-service teachers at a large public university in the southeastern United States. The course was titled “Introduction to Computing for Teachers.” The purpose of the course was to introduce instructional technologies to undergraduates and provide guidance on how to plan and design meaningful teaching practices in K-12 classrooms using technology.

This course was open to other majors at the university, so students were composed of education majors and non-education majors from different years. According to a course survey conducted in the spring semester of 2018, half of the students who took this course were undergraduate education majors, but the other half were from colleges all over the campus (Clement, Hayes, & Helmly, 2018). Several sections of this course were offered each semester. The three-credit course was 16 weeks long and met 150 minutes per week (twice per week for 75 minutes or three times per week for 50 minutes).

This study recruited participants from ten sections of this course in the early Spring semester of 2019. There were 11-18 undergraduates enrolled in each section that semester, but participation in the study was voluntary. Also, the learning activities and tasks required to be completed for the study would not be recorded as a course grade. Because the participants’ backgrounds varied, this study collected the demographic information of each participant such as gender, major, year, and the reasons to take this course in the spring semester of 2019 to provide perspectives in the discussions of research findings. The study also asked students to self-report their prior knowledge and experience regarding designing and conducting technology integration in the classroom by rating on a scale ranging from 0 to 10. In order to recruit students to participate in the study, this researcher received support from the course instructors. The instructors of nine sections would grant a late pass to each student who participate in the study. The late pass could be used to excuse an absence or to submit an assignment up to 24 hours after the due date without penalty. One section instructor of a section would grant each participant two bonus points as the practice of late pass was not adopted in the class.

Context

The study was conducted in the classroom where each section was normally given. The researcher was invited as a guest speaker to the classes. The researcher published the video modeling modules on a website created with Google Sites. Each module used a different instructional method. Students who had signed a consent letter logged into their class website to access their designated video modeling module. The majority of participants used their own laptops and headphones to take video modeling instruction and complete the study, while several students used laptops provided by their instructors and headphones provided by the researcher. Each participant worked independently, proceeding through the research instruction at their own pace.

Instructional Materials

This study used a video entitled *Singapore's 21st-Century Teaching Strategies*. Edutopia published this video at YouTube. YouTube is a video-sharing website. This video is available for download and sharing. The use of the video for educational purposes falls into the category of fair use. This video presents how Ngee Ann Secondary School in Singapore develops and implements technology integration in order to engage students in classroom instruction and develop students' 21st-Century skills.

The whole video lasts for 7 minutes and 34 seconds. The video content covers multiple elements, including (1) the introduction to the school and interpretations of technology integration practices recorded in the video by the head of the school, (2) the speech regarding the significance of technology integration on developing students 21st-century skills by a representative from the Department of Education, (3) an academic speech regarding meaningful technology integration by a university professor, (4) three exemplary technology integration practices in the real classroom, (5) teacher's professional development activities. These elements are not independent from each other because students need to combine information across these sources to answer guiding questions and complete the posttest. For example, the evaluation of each technology integration practice requires to carefully observe students' interactions with the teacher and other students in the classroom; meanwhile, students had to adopt the perspectives of the school administer, experts and other parties to fill in their information gaps or misconceptions about the topic. Thus, this video presented moderate complexity of content based on Sweller's (2010) concept of element interactivity.

The topics and content addressed in this video matched the topics and content covered in the recruited course. The researcher invited two education-major undergraduates and two instructors of the technology integration course to view this video. They reported that the video was interesting and helpful for learning meaningful technology integration in the classroom. Table 4 summarizes the information about the whole video tutorial.

Table 4.

Summary of the Whole Video

Topic	**Singapore's 21st-Century Teaching Strategies**
Objectives	Video utilization in this study is expected to: 1. Improve students' professional knowledge that empowers them to: (1) discern the roles of teachers, students, and technology in meaningful technology integration practices. (2) develop an awareness of combining developing students' 21st-Century skills into technology integration practices. 2. Improve the evaluation ability that empowers learners to: (1) criticize and assess the quality of technology integration practices from global and more comprehensive perspectives.
	This video presents how Ngee Ann Secondary School in Singapore developed and implemented technology integration in the classroom. The video contents cover the leadership, teachers' professional development, and three instruction practices in the real classroom that emphasize the use of technology, digital media, and the integration of 21st-Century skills.
Length	7 minutes and 34 seconds.
Resource	https://www.youtube.com/watch?v=M_pIK7ghGw4&t=103s

Instructional Interventions

Segmenting the video. This study used a system-manipulated segmentation method. The researcher subdivided the whole video into six segments. The rationale for subdividing the video was scene change because spatiotemporal changes in this video indicated that the content was shifting to a new instructional event (Carlson et al., 2018; Doolittle et al., 2015; Fiorella & Mayer, 2018). Each video segment addressed a different scenario recorded in the school. Table 5 summarizes the content about each video segment scenario.

Table 5

Summary of Six Video Segments

Video Segments	Starting Ending Time	Video Content
Segment 1	0:00-2:28 minutes	The school principal, an official of the Ministry of Education in Singapore, and a professor of Singapore National Institute of Education give speeches that emphasize the necessity of conducting technology integration in the classroom to improve learning engagement. They also describe the roles of teachers and students in developing students' 21st-Century learning skills.
Segment 2	2:28-3:15 minutes	A male science teacher uses an instant messaging tool to teach velocity in his class that accommodates 40 students. The camera shows that the teacher proposes a question and asks students to use their cell phones to tweet their answers by following a specified format. The camera also shows students using their cell phones to tweet their responses, and the teacher demonstrates responses on a big screen of the classroom. In this video clip, the school principal uses the practice as an example to describe how the technology can be leveraged to significantly impact classroom instruction.
Segment 3	3:15-4:05 minutes	A male art teacher uses a Second Life art gallery to teach art. He explains that the school established the art gallery by including artworks by local artists. He also illustrates how he uses Second Life to engage students in collaborative learning and critical learning. The camera shows students' working in pairs, discussing the exhibited artworks, reading the notes left by other students, and leaving their notes at the gallery.
Segment 4	4:05-5:23 minutes	A female science teacher creates a learning community on Facebook to teach the concept of

		the electron. She notices that many students are very interested in Facebook and distracted by it in the classroom, so she decides to turn the distraction tool into an engaging learning tool by creating a learning community on Facebook. The camera shows students' working actively and collaboratively and posting and answering questions in the classroom.
Segment 5	5:23-6:42 minutes	A group of teachers uses video modeling and online conferencing tools for professional development. They use a recorded classroom instruction as content for discussions. Also, they exchange teaching plans with a group of Western teachers on Skype. Then, two female teachers give a speech about their experience and feelings about the significance and challenge of integrating technology in the classroom.
Segment 6	6:42-7:34 minutes	The school principal gives a speech by summarizing that technology integration is an adaptive approach to students' changing demands. The camera shows a scenario that students are engaged in rowing workouts while a digital screen shows students' rowing speed.

Add subheadings to video segments. Each video segment was given a number listed subhead to help students develop an initial idea of the video content. The researcher learned this design practice from the Adobe.com website where video tutorial is designed using this method ("Get to know photoshop," 2018). Because the study adopted a student-controlled design, each student independently viewed videos and completed study tasks on their laptops. Figure 4 shows an example of the segmentation design, in which a subhead was given a video segment.

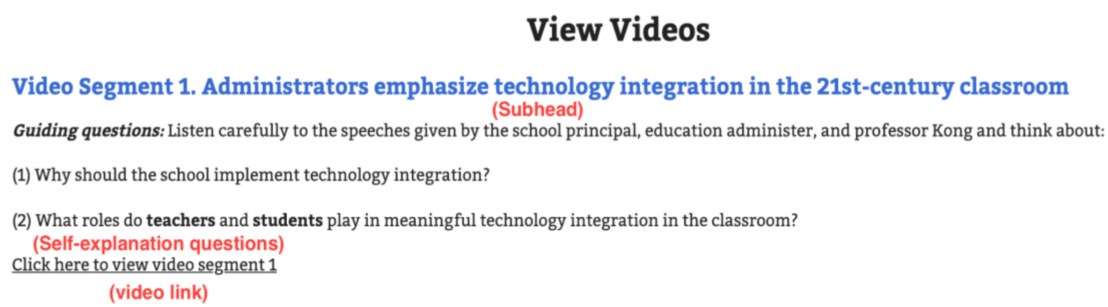


Figure 4. An example of video segmentation design

Create self-explanation questions. The development of the self-explanation questions utilized the focused format. Focused self-explanation questions can orient students' attention to critical information within the video (Wylie & Chi, 2014) and facilitate students to integrate the new information with their existing schemas to form a new mental model (Chi, 2000; Mayer, 2014). The new mental model is conducive for their interpreting information that they hear and see within the specific learning environment in the video (Wylie & Chi, 2014); for example, the guiding question 5 states that "Please combine the teacher's speech with students' performance to think about: How does the teacher use a Second Life art gallery to improve students' learning environment, as opposed to organizing a museum field trip?" This question could orient participants' attention to the teacher's speech and students' performance, facilitate them to integrate their hearing and seeing into interpreting the impact of using technology on students' learning involvement, and encourage them to compare the technology-enhanced learning experience with a traditional learning experience (i.e., a museum field trip).

The researcher created seven focused self-explanation questions for the six video segments, one or two questions for each video segment. The focused self-explanation questions were termed *guiding questions* in this study to avoid confusions due to academic jargon. The development of these guiding questions incorporated constructive comments from four people. One was a doctoral student in the Department of English Literature, the second was a faculty member who taught the technology integration course for over 12 years, and the third and fourth were undergraduates who took this technology integration course in the Fall semester of 2018. They helped the researcher to check that these questions could facilitate students to *understand* the main ideas of each video segment, *interpret* the happenings in the classroom, and finally *criticize and evaluate* the roles that different stakeholders of a technology integration classroom— the teacher, students, and technology—play in each case and their impact. According to Roy and Choi (2005), psychological mechanisms underlying the self-explanation principle are "the generation of learner-initiated inferences and the monitoring and repair of knowledge." (p.278). Table 6 lists the seven guiding questions and their corresponding video segments, summarizing the rationales for developing the questions.

Table 6

Developing Self-explanation Questions for Video Segments

Video Segment and Subhead	**Self-explanation Questions**	**Rationales**
Video Segment 1. Administrators emphasize the significance of technology integration in the 21st-century classroom	Listen carefully to the speeches given by the school principal, education administer, and professor Kong and think about: (1) Why should the school implement technology integration? (2) What are teachers' roles in meaningful technology integration in the classroom?	1. Facilitate learners to identify and fill in the gaps between the learning materials and their existing schema. (Wylie & Chi, 2014; Yeh et al., 2010). 2. Direct students' attention to critical information within an instructional scene (Wylie & Chi, 2014; Yeh et al., 2010).
Video Segment 2. A science teacher uses an instant messaging tool to teach velocity	Combine the school principal's speech and the technology integration case to think about: (3) How does the teacher use the instant messaging tool to improve classroom engagement? (4) What is the main instruction goal that the teacher conducts the technology integration practice?	1. Direct students' attention to critical information within an instructional scene (Wylie & Chi, 2014; Yeh et al., 2010). 2. Encourage students to synthesize information when evaluation a teaching practice (Wylie & Chi, 2014).

Video segment 3. An art teacher uses a Second Life art gallery to teach art	Please combine the teacher's speech with students' performance to think about: (5) How does the teacher use Second Life art gallery to improve his students' learning involvement, as opposed to organizing a museum field trip?	1. Encourage students to synthesize information when evaluation a teaching practice (Wylie & Chi, 2014).
Video segment 4. A science teacher uses Facebook to teach electrons	Please combine the teacher's speech and students' performance to think about: (6) How does the teacher use Facebook to engage students in an academic way?	1. Direct students' attention to critical information within an instructional scene (Wylie & Chi, 2014; Yeh et al., 2010). 2. Encourage students to synthesize information when evaluation a teaching practice (Wylie & Chi, 2014).
Video segment 5. Teachers use video modeling and online conferencing tools for professional development	(7) Why do teachers need to conduct ongoing professional development, specifically in meaningful technology integration?	1. Encourage students to synthesize information when evaluation a teaching practice (Wylie & Chi, 2014).
Video segment 6. Technology integration is an adaptive approach to students' changing demands	No guiding question because this part is a summary of the topics addressed in the video.	

Two research conditions using a self-explanation design. A self-explanation design was used in two experimental conditions:1) the self-explanation condition, and 2) the combination condition. In the self-explanation condition, the video modeling instruction used a whole video, so the seven self-explanation questions were all placed above the link to the video. In the combination condition, the instruction used segmented videos, so one or two guiding questions related to the video content were placed above the video link.

In the self-explanation condition. The first research condition adopting a self-segmentation design was the self-explanation condition. Figure 5 shows how the self-explanation questions were integrated into this self-explanation instructional design. However, there was some concern about the effectiveness of a self-explanation design in producing germane load as intended. Kalyuga (2008) and Sweller (2006) contended that the self-explanation effect was unlikely to be productive if learners had to study complex materials that had the potential to engender cognitive overload. In this design, students would view the whole video from the beginning to the end. However, viewing a whole video may not free enough cognitive resources for accommodating self-explanation activities that require students to read and think about seven guiding questions. Therefore, self-explanation activities may work as extraneous load activities rather than germane load activities in this situation.

View Videos

(please read the following guiding questions before viewing the video! Also, take notes to answer these questions while viewing the video!)

Guiding questions:

In the first scenario, you will watch the school principal, education administer, and a university professor are talking. Listen carefully to their speeches and think about:

(1) Why should the school implement technology integration?

(2) What roles do teachers and students play in meaningful technology integration in the classroom?

Next, you will watch a science teacher uses an instant messaging tool to teach velocity.

Please combine the school principal's speech with the technology integration case to think about:

(3) How does using the instant messaging tool help students engage in classroom?

(4) What is the main instruction goal that the teacher wants to develop his students in this case?

Then, you will watch an art teacher uses Second Life art gallery to teach art.

Please combine the teacher's speech with students' performance to think about:

(5) How does the teacher use Second Life art gallery to improve students' learning involvement, as opposed to organizing a museum field trip?

And then, you will watch a science teacher uses Facebook to teach the electron.

Please combine the teacher's speech and students' performance to think about:

(6) How does using Facebook help the teacher engage students in an academic way?

Lastly, you will watch teachers use video modeling and online conferencing tools for professional development.

(7) Why do teachers need to conduct ongoing professional development, specifically in meaningful technology integration?

Singapore's 21st-Century Teaching Strategies

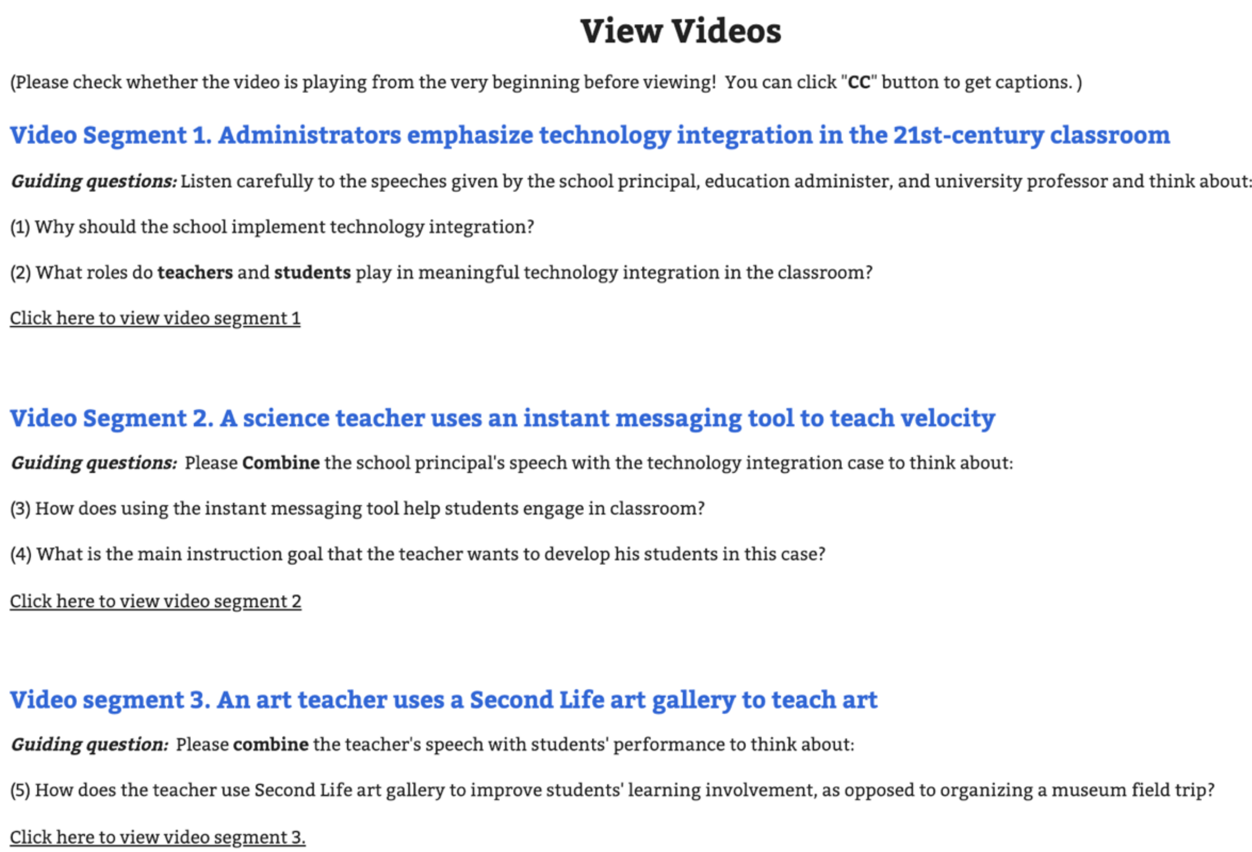
Click here to view the video

(Please check whether the video is playing from the very beginning before viewing! You can click "**CC**" button to get captions.)

Figure 5. A self-explanation condition under the self-explanation condition

Aiming at reducing some cognitive demands, the researcher used conjunctions—in the first scenario, next, then, and then, and lastly—to divide the guiding questions by video scene and avoid potentially overwhelming the students. Moreover, the researcher printed out self-explanations on a note sheet (See Appendix D) and left space for responding to each question. Instead of constant toggling back and forth to read the seven guiding questions, students just read through those questions before viewing the video. Using a note sheet could save mental effort in memorizing the guiding questions.

In the combination condition. The second research condition adopting a self-segmentation design was the combination condition. This design used segmented videos, with each segmented video focusing on one topic or technology integration case, so that the intrinsic load demands for viewing the whole video could be reduced. Furthermore, only one or two guiding questions were proposed and placed above each video segment. Figure 6 shows how the self-explanation questions were integrated in the combination design.



Video segment 4. A science teacher creates a learning community on Facebook to teach electrons

Guiding question: Please **Combine** the teacher's speech and students' performance to think about:

(6) How does using Facebook help the teacher engage students in an academic way?

Click here to view video segment 4.

Video segment 5. Teachers use video modeling and online conferencing tools for professional development

Guiding question:

(7) Why do teachers need to conduct ongoing professional development, specifically in meaningful technology integration?

Click here to view video segment 5

Video segment 6. Technology integration is an adaptive approach to students' changing demands

Click here to view video segment 6

*Figure 6.*A self-explanation design under the combination condition.

As is shown in Figure 6, questions 1 and 2 were created for video segment 1; questions 3 and 4 were created for video segment 2; questions 5, 6, 7 were created for video segments 3, 4, and 5 respectively. There were no guiding questions for the video segment 6 because the video content was mainly summarizing the previous content. Moreover, each student working in the combination condition received a note sheet before viewing their videos. The design of the note sheet was the same as that used in the segmentation condition.

The goal of placing guiding questions before the video in both conditions was to require participants to read the guiding question(s) before viewing the video, so that they could develop some ideas about the critical information in the video before video-viewing. Taking notes would ensure that students continued engaging with the video through the questions. Students' notes were collected after the study and used as part of the evidence that they had participated in this study.

Taking notes. The goals of requiring participants to take notes while viewing a video include: (1) forcing them to read the guiding questions and avoid some students' skipping the procedure, and (2) helping students recall memories when students are taking their posttest.

Mayer et al. (2003) also integrated the note-taking design into their self-explanation study. Mayer et al. gave a sentence of instruction to indicate the significance of taking notes and the knowledge-transfer questions on the sheets for taking notes. Thus, this study also adopted note-taking into the self-explanation design. The researcher created two different formats of note sheet because two research groups—the control group and the segmentation group—were not provided guiding questions while two other groups—the self-explanation group and the combination group —were provided guiding questions. For the groups provided guiding questions, the note sheet printed the guiding questions for facilitating students to indeed use the self-explanation design. Appendix C is the note sheet for groups without guiding questions. Appendix D is the note sheet for groups with guiding questions.

Web-based video model instruction. A website-based video modeling instruction program was developed to guide participants through the video modeling instructions. The website was composed of four video modeling modules (see Figure 7).[1] Each module represented one research condition design (See Table 7). Video modeling module 1 was designed for the control condition, and video modeling modules 2-4 were designed for the three experimental conditions.

*Figure 7.*Home page of the web-based video modelling instruction program

[1] This is the website link: https://sites.google.com/view/technologyintegrationsingapore/home.

Table 7

Summary of Instructional Features in Video Modeling Instruction Module

Video Modeling Modules	**Research Conditions**	**Adopted Design Principles**	**Video Types**	**Self-explanation Questions**
Module 1	Control	None	A whole video	No
Module 2	Segmentation	Segmentation	Segmented videos	No
Module 3	Self-reflection	Self-explanation	A whole video	Yes
Module 4	Combination of segmentation and self-reflection	Combination of Segmentation and self-reflection	Segmented videos	Yes

As is shown in Table 7, participants in the control condition accessed module 1 to view the video in its entirety (see Appendix E). No instructional intervention was implemented in module 1. The segmentation experimental group accessed module 2, which adopted design principles and guidelines about segmentation (see Appendix F). The self-explanation experimental group accessed module 3, which adopted the design principles and guidelines about self-explanation (see Appendix G). Finally, the segmentation and self-explanation experimental group accessed module 4, which adopted the design principles and guidelines regarding both segmentation and self-explanation (see Appendix H).

All of the four video modeling modules comprised three components: (1) module instructions, (2) learning objectives, and (3) view video(s). Figure 8 shows a screenshot of the instructions and learning objectives. The section of module instruction described the video content, length, and the instructions of guiding questions. The section of learning objectives described two main learning objectives that this video modeling was expected to achieve in terms of improving students' professional knowledge base and evaluation abilities regarding technology integration.

Instructions

You will view videos that recorded how Ngee Ann Secondary School in Singapore develops and implements technology integration in the classroom. The video contents cover the leadership, teachers' professional development, and **THREE** instruction practices in the real classroom that emphasize the use of technology, digital media, and the integration of 21st-Century skills.

In this module, you will view a video. **Please watch the video from the beginning to the end!!** You can feel free to pause or rewind as you like, but **skipping and fast-forwarding are NOT allowed** for ensuring the quality of this study. The total video length is **7 minutes and 32 seconds**.

Furthermore, please **READ the guiding questions** provided before the video. Also, please **RESPOND to the questions by taking notes** while viewing the video.

This video was published by Edutopia on YouTube at https://www.youtube.com/watch?v=M_pIK7ghGw4.

Learning Objectives

Through taking this video modeling instruction, you are expected to:

1. **Improve your professional knowledge** that empowers you to :

   (1) discern the right roles that teachers, students, and technology should play in meaningful technology integration practices.

   (2) develop an awareness of combining developing students' 21st Century skills into technology integration practices.

2. **Improve the evaluation ability** that empowers you to:

   (1) criticize and assess the quality of technology integration practices from global and more comprehensive perspectives.

*Figure 8.*A screenshot of the instructions and learning objectives for video modeling

Data Collection Procedures

The study was administered in the early spring semester of 2019. During a class period prior to the class of conducting the study, the researcher gave an introduction to students about the study and its relevance to their course study in each section; then, students were asked for their consent to participate in the study. The consent letters were printed out and distributed to students in the classroom. In the class period of conducting the study, the researcher randomly assigned each participant to one of the four research groups and gave each participant a different research identity number. Participants wrote their identity numbers on each test paper and survey as a substitute for their names. Figure 9 summarizes the data collection procedures.

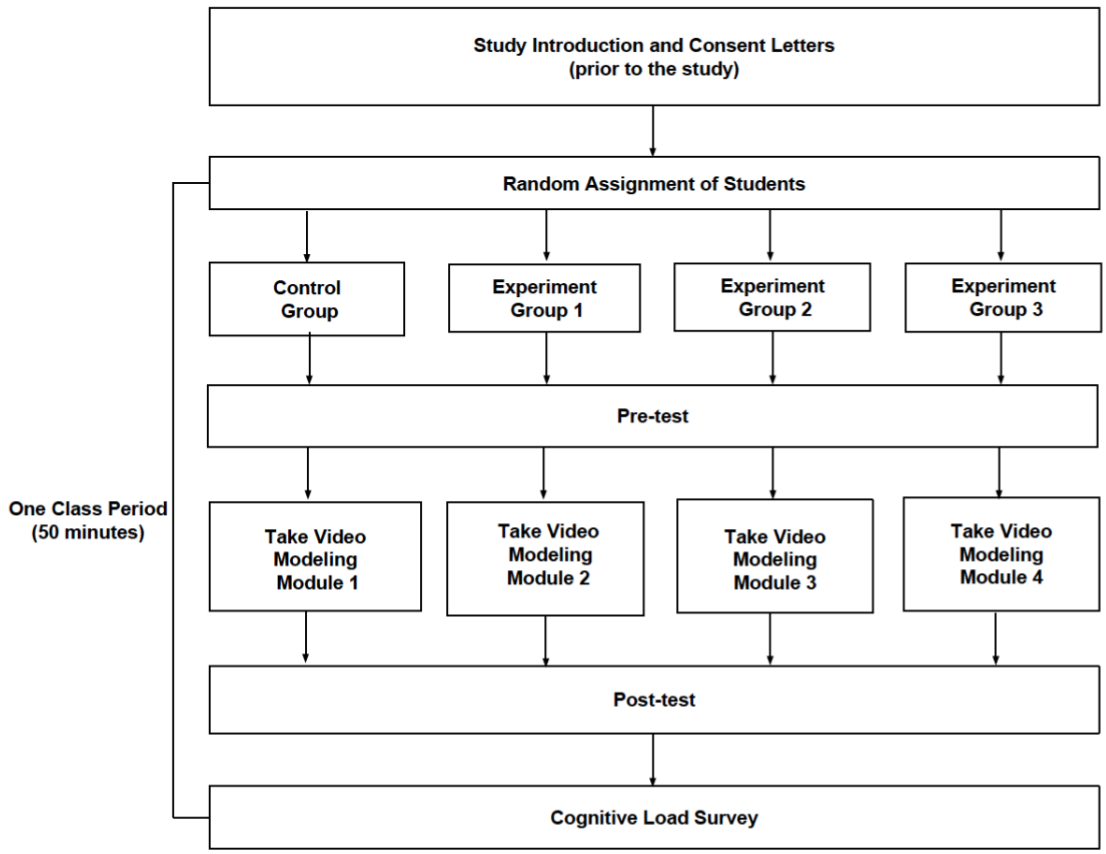


Figure 9. Data collection procedures

As is shown in Figure 9, there were four tasks included in this study, and they were (1) completing an online pretest, (2) taking video modeling instruction, (3) completing an online posttest, and (4) completing an online cognitive load survey. The researcher created four shared Google documents for the four research groups respectively for posting the study task links. The documents were published by instructors on their class websites. Because this video instruction adopted a learner-controlled design, participants independently took the video modeling instruction and completed the tests and surveys. Participants used their own computers and earphones to complete the study tasks. Some participants used the laptops in the mobile cart in the classroom. The researcher prepared 10 headphones in case that some students would forget to bring about their earphones.

Data Collection Tools

Concerning dependent variables in the study, the researcher specifically examined the effects of video modeling that incorporated segmentation and self-explanation questions into the instructional design on three types of cognitive load and learning achievement of technology integration knowledge and evaluation abilities. The tools used to collect the needed data for analysis include a cognitive load survey questionnaire and a pre- and posttest quiz. The quiz used for the pre- and posttest were exactly same, except that the scale for self-reporting prior knowledge and experience regarding technology integration in the classroom was used only in the pretest.

The Quiz for Technology Integration Knowledge and Evaluation

A quiz was administered before and after students' viewing the video(s). The quiz was composed of 10 multiple choice questions and administered before and after video modeling instruction (see Appendix I). The quiz was developed by the researcher who conducted a three-phase development process to achieve content validity. Content validity of a quiz is concerned with whether or not a quiz is relevant to test participants, whether or not the purpose of a quiz is clear and transparent for test participants (Jenney & Campbell, 1997), and whether or not the content of a quiz is representative of what was taught (Jenney & Campbell, 1997; Sercu, 2010). The quiz development phases were divided into (1) developing the initial quiz, (2) incorporating a content expert's comments and perspectives, and (3) testing the quiz with the targeted participants.

Developing the initial version of the quiz. The quiz aimed to examine the effects of video modeling instruction on students' cognitive load and learning achievement, so the test questions were designed to represent knowledge and information presented in the video. Also, the study integrated the content of one seminal reading material of the course into the test design in order to examine participants' prior knowledge in technology integration. The reading material is entitled "*Goal of Technology Integrations: Meaningful Learning,"* which is the first chapter of the book *Meaningful Learning with Technology* (4th ed.) by Howland et al. (2012). Moreover, part of the study's effort was to investigate the potential of video modeling instruction on developing students' evaluation abilities, so the researcher used the three technology integration practices in the video for case studies. Based on the above-mentioned consideration, the researcher developed the initial quiz including 15 single-answer questions.

Incorporating a content expert's perspectives. After the researcher had developed the initial version of the quiz, she wanted to get input from content experts in technology integration to improve the quiz design. According to Shepard (1993), "the method for establishing or evaluating the reasonableness of test content is usually expert judgment." (p.413). She got the support from a faculty member who had taught the technology integration course for over 12 years. The researcher met the faculty member in person twice. Each meeting lasted for half-an-hour. The first meeting was before the faculty member's reviewing and commenting on the quiz. The second meeting was after the researcher had revised the quiz based on the faculty member's comments. The faculty member provided many constructive comments for improving the quiz design from three aspects, including (1) correlating each of the 15 questions to the topics of both the technology integration course and the video, (2) ensuring that the questions provided a comprehensive examination of students' knowledge and evaluative abilities, and (3) avoiding ambiguity in the answer choices.

Testing the quiz. Because the participants of the study were undergraduates who took the technology integration class, undergraduates' input was critical for the quiz quality. The researcher invited two undergraduates who took the technology integration course in 2018 to test the quiz one by one. The researcher made the first appointment with one of the undergraduates. The researcher followed the study procedures to administer the study with the student. After the student had completed the study tasks, the researcher talked with her to collect comments on the quiz. She provided feedback to improve the clarity of the wording and expressions from the undergraduate perspective. After the researcher revised the quiz based on the first student's comments, she made an appointment with the second undergraduate by following the same procedures administered on the previous student. The second student confirmed the overall quality of the quiz. The researcher paid the students 15 and 10 dollars respectively for the testing work.

Quiz structure and content. Through several rounds of revision and improvement, the final version of the quiz comprised three parts and 19 questions. The three parts are (1) nine questions for a demographic information survey, (2) five questions for a professional knowledge survey on technology integration, and (3) five questions for case studies of technology integration in the classroom. For the part one, there are nine questions to collect participants' demographic information, including research ID, the reason(s) to take the technology integration course, gender, year, major, self-rated prior knowledge and experience regarding designing and conducting technology integration in the classroom as a teacher. For the part two, there are five single-answer questions that examine students' knowledge base of meaningful technology integration from different aspects. The aspects include (1) definition, (2) considerations for planning and implementing technology integration in the classroom, (3) identification of the roles of teachers in technology integration, (4) identification of the roles of students in technology integration, and (5) identification of the roles of technology in meaningful learning. For the part three, there are three case studies and five single-answer questions. Through case studies, the study examines students' evaluative abilities of meaningful technology integration. Based on participants of in the pilot study, the scale's Cronbach's coefficient alpha value was .512 for the pretest. The Cronbach's Alpha value was acceptable based on the very few literatures that calculated the Cronbach's coefficient alpha value for quizzes used in research studies; for example, Kopcha and Sullivan (2008) examined the effects of learner preferences and prior knowledge on learning achievement in a learner-controlled computer-based instruction in their study, and they reported the Cronbach's coefficient alpha for the used pretest quiz was .59. However, Leppink et al. (2013) examined the impact of instructional design on cognitive load in their study, and they used a two-question quiz in the prior knowledge test; yet they did not report the Cronbach's coefficient alpha value regarding the quiz. Mayer et al. (2003) examined the impact of self-explanation instruction design on learning achievement in their study, and they used a seven-question transfer test sheet for conducting the posttest; however, they did not report the Cronbach's coefficient alpha value regarding the transfer test. Moreover, Chu (2014) conducted a pretest-and-post experimental study to examine potential negative effects of mobile learning on Students' learning achievement and cognitive load, and the author did not report Cronbach's coefficient alpha value for the pretest quiz comprising 30 multiple-choice items and the posttest quiz comprising 40 multiple-choice items. Table 8 summarizes structure and content of the quiz that is used for both a pretest and a posttest. Appendix I provides all the questions of the quiz.

Table 8

Summary of the Structure of the Quiz

Parts	Content Focus	Number of Questions
One	Demographic information	9
Two	Professional knowledge of meaningful technology integration.	5
Three	Case studies of the three technology integration practices in the video	5

Cognitive Load Survey Questionnaire

A ten-item cognitive load questionnaire was developed to examine students' perceived cognitive load while taking video modeling instruction. The questionnaire was modified from the instrument developed by Leppink et al. (2013). Table 9 summarizes Leppink et al.'s scales (2013) and the modified scales used in this study by changing the wording that was associated with video modeling.

Table 9

Summary of the Modified Cognitive Load Scales

Leppink et al. (2013)	The Modified Scales for This Study
1. The topic/topics covered in the activity was/were very complex. (IL 1)	1. The topics covered in the video(s) were very complex. (IL 1)
2. The activity covered formulas that I perceived as very complex. (IL 2)	2. The video(s) covered content that I perceived as very complex. (IL 2)
3. The activity covered concepts and definitions that I perceived as very complex. (IL 3)	3. The video(s) covered very complex concepts and teaching practices regarding technology integration. (IL 3)
4. The instructions and/or explanations during the activity were very unclear. (EL 1)	4. The video modeling instruction method(s) (e.g., viewing a whole video, viewing segmented videos, providing guiding questions) made me invest a very high mental

	effort in understanding the video content.
5. The instructions and/or explanations were, in terms of learning, very ineffective. (EL 2)	5. The video modeling instruction method(s) (e.g., viewing a whole video, viewing segmented videos, providing guiding questions) were, in terms of learning, very ineffective. (EL2)
6. The instructions and/or explanations were full of unclear language. (EL 3)	6. The video modeling instruction method(s) (e.g., viewing a whole video, viewing segmented videos, providing guiding questions) were distracting. (EL 3)
7. The activity really enhanced my understanding of the topic(s) covered. (GL 1)	7. The video modeling instruction method(s) (e.g., viewing a whole video, viewing segmented videos, providing guiding questions) really enhanced my understanding of the topics covered in the video. (GL 1)
8. The activity really enhanced my knowledge and understanding of statistics. (EL2)	8. The video modeling instruction method(s) (e.g., viewing a whole video, viewing segmented videos, providing guiding questions) really enhanced my knowledge and understanding regarding technology integration. (GL 2)
9. The activity really enhanced my understanding of the formulas covered. (GL 3)	9. The video modeling instruction method(s) (e.g., viewing a whole video, viewing segmented videos, providing guiding questions) really enhanced my understanding of content covered in the video. (GL3)
10. The activity really enhanced my understanding of concepts and definitions. (GL 4)	10. The video modeling instruction method(s) (e.g., viewing a whole video, viewing segmented videos, providing guiding questions) really enhanced my understanding of concepts and teaching practices regarding technology integration. (GL4)

Among the ten items, items 1-3 addressed intrinsic load (IL), and items 4-6 addressed extraneous load (EL), and items 7-10 addressed germane load (GL). Each of the ten items used a seven-point scale, from strongly disagree (1) to strongly agree (7). Leppink et al. (2013) found that Cronbach's alpha value was .81 for items 1-3, .75 for items 4-6, and .82 for items 7-10 in their study. Also, Leppink et al. (2013) found that the three factors were significantly correlated: the correlation between intrinsic load and extraneous load was .61 ($p < .001$), the correlation between intrinsic load and germane load was -.36 ($p < .001$), the correlation between extraneous load and germane load was -.56 ($p < .001$). These findings support the validity of this three-factor instrument for examining different types of cognitive load.

Leppink et al. (2013) administered this 10-item three-factor instrument in a short experiment that examined the effects of treatment orders manipulated between two different explanation formats (i.e., text format and formula formation) on cognitive load and learning outcomes. The experiment was conducted after a one-hour lecture that explained two basic inferential statistical concepts and definitions as well as relevant formulas covered in the experiment. 58 university freshmen enrolled in a statistics course were assigned randomly to either of two treatment order conditions (Leppink et al., 2013). Leppink et al. (2013) found the followings regarding cognitive load: 1) more prior knowledge predicts lower intrinsic load; 2) extraneous load is increased significantly for the formula format when the formula format is presented before the text format (because learners are less familiar with formula format than with text format); 3) the text format imposes significantly more germane load when presented after the formula format. Also, Leppink et al. (2013) found that higher prior knowledge was a statistically significant predictor for higher post-test performance. Findings of this experiment also supported the validity of the instrument. According to Leppink et al. (2013), these findings provide “evidence for the validity of the three-factor solution underlying Items 1-10” (p. 1069). Moreover, Leppink et al. (2013) examined a 9-point mental effort rating scale by the Paas’s (1992) and Paas et al. (1994). The scale is often stated in the following expression: In solving or studying the preceding problem, I invested (...) mental effort (Leppink et al., 2013; Paas, 1992;

Yeh et al., 2010; Mayer & Chandler, 2001). This scale "has been used intensively and have been identified as reliable and valid estimators of overall cognitive load" (Leppink et al., 2013, p. 1059), however the scale found to have relatively weak loadings on all three factors in a confirmatory factor analysis in the study conducted by Leppink et al.'s (2013).

Based on participants of the study, Cronbach's coefficient alpha for the survey instrument was .792 for the 10 items, .928 for items 1-3 on intrinsic load, .405 for items 4-6 on extraneous load, and .917 for items 6-9 on germane load. After excluding the item 4, Cronbach's coefficient alpha for the nine-item survey instrument was .749, .929 for items 1-3, .760 for items 5-6, and .919 for items 6-9.

The correlations between each item were calculated (see Figure 10). As is shown in Figure 10, the correlations among the three items of intrinsic load were significantly correlated, with *r* values ranging from .778 to .895; the correlations between the two items of extraneous load were significantly correlated with both *r* values of .623; the correlations among the four items of germane load were significantly correlated, with *r* values ranging from .688 to .867. Thus, the study used the nine items to analyze students' responses in the cognitive load survey.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	1	.895**	.778**	.118	.089	.217*	.282**	.292**	.291**
2	.895**	1	.778**	.183*	.092	.257**	.287**	.292**	.312**
3	.778**	.778**	1	.072	.007	.335**	.373**	.366**	.363**
4		(Intrinsic Load)		1	.623**	-.366**	-.316**	-.310**	-.250**
5				.623**	1	-.484**	-.399**	-.332**	-.270**
6				(Extraneous Load)		1	.845**	.711**	.688**
7						.845**	1	.738**	.686**
8						.711**	.738**	1	.867**
9						.688**	.686**	.867**	1
							(Germane Load)		

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Figure 10. Correlations between each type of the cognitive load questionnaire

The correlations between each factor of cognitive load was also calculated (see Figure 11). If the correlations between the three types of cognitive load were > .65, then we could assume that the three measures are examining the same thing. However, the correlation was .473 ($p < .01$) between the intrinsic load and extraneous load, and correlation was .364 ($p < .01$) between the intrinsic load and germane load. The factors of cognitive load are correlated moderately at best. Thus, the findings supported the Leppink et al.'s (2013) findings that the three-factor instrument was examining different types of cognitive load.

	Intrinsic Load	Extraneous Load	Germane Load
Intrinsic load	1	.473**	.364**
Extraneous load		1	-.130
Germane load			1

**. Correlation is significant at the 0.01 level (2-tailed).

*Figure 11.*Correlations between the three factors of cognitive load

The intrinsic load scores would be the sum of the ratings of items 1-3, so the minimum score was 3 points, and the maximum score was 21 points. The extraneous load scores would be the sum of the ratings of items 5-6, so the minimum score was 3 points, and the maximum score was 14 points. The germane load scores would sum up the rating s of items 6-9, so the minimum score was 4 points, and the maximum score was 28 points.

Moreover, the researcher was interested in exploring students' thinking underlying their ratings. Thus, open questions were added at the end of cognitive load survey to gather supplemental information. Three opened questions were provided for the control group and the segmentation group, and the questions were about their perspectives of the video itself, their preference for viewing a whole video or video segments subdivided from the whole video, and their expectations of the provision guiding questions. Four opened questions were provided for the self-explanation group and the combination group, and the questions were about their perspectives of the video itself, their preference for viewing a whole video or video segments subdivided from the whole video, their perspectives of the guiding questions and the amount of the guiding questions. Appendix J provides the open questions together with the cognitive load survey questionnaire.

Data Analysis Plan

The collected data would be analyzed using descriptive statistics to examine the minimum, maximum, medians, the group means, and standard deviations of pretest scores, posttest scores, and self-reported cognitive load ratings. Pretest scores would be used as prior knowledge that would be treated as the covariate in the data analysis to partial out the variance associated with the instructional scaffolds and to make the analysis more sensitive and accurate. Also, seven separate multiple linear regression models would be used to examine the main effects of video modeling instruction methods on three dependent variables of cognitive load—intrinsic load, extraneous load, and germane load—and three dependent variables of learning outcomes—professional knowledge, evaluative ability, and the overall learning performance—by covarying students' prior knowledge base. Table 10 provided an outline for the data collection tools and analysis strategies for each research question

Table 10

Summary of Data Collection Tools and Analysis Strategies by Research Question

Research questions	**Data collection tools**	**Data analysis strategies**
RQ1. What are the effects of segmentation and self-explanation design on learners' cognitive load when incorporating prior knowledge into consideration?	- Cognitive load survey - The technology integration knowledge and evaluation abilities quiz	- Descriptive statistics - Multiple Linear Regression

RQ2. What are the effects of segmentation and self-explanation design on learners' learning achievement when incorporating prior knowledge into consideration?	- Cognitive load survey - The technology integration knowledge and evaluation abilities quiz	- Descriptive Statistics - Multiple Linear Regression
RQ3. How does learning achievement at the posttest relate to prior knowledge and cognitive load?	- Cognitive load survey - The technology integration knowledge and evaluation abilities quiz	- Pearson correlations
RQ4. How do students perceive the segmentation and self-explanation designs used in the study?	- Open-ended questions added to the end of the cognitive load survey questionnaire	- Descriptive Statistics

Independent Variables

This study examined two independent variables: (1) prior knowledge, and (2) video instruction.

(1) Prior knowledge

Prior knowledge was the covariate that was a continuous variable. Prior knowledge was obtained from students' overall scores in the pretest.

(2) Video instruction

Video instruction is a categorical independent variable that was divided into four types:

a. Video instruction using a segmentation design (i.e., experimental group 1).

b. Video instruction using a self-explanation design (i.e., experimental group 2).

c. Video instruction combining segmentation and self-explanation designs (i.e., experimental group 3).

d. Video instruction without using any interventions (i.e., the control group).

Dependent Variables

This study would like to examine the effects of video modeling instruction (by controlling for prior knowledge) on two main factors: (1) Cognitive load, and (2) Learning achievement. Both of them were continuous variables.

(1) Cognitive load

a) Intrinsic load

b) Extraneous load

c) Germane load

(2) Learning achievement

a) Professional knowledge

b) Evaluative ability

c) Overall performance

Effect Coding. The effect coding method was used to code the categorical independent variable—video modeling instruction—by assigning a set of codes to each level of a categorical variable. According to the rule of the effect coding method, one group has to be removed for the analysis to get rid of linear dependency (Pedhazur, 1982). However, removing a group during coding does not mean that the data of the removed group will be excluded out of the data analysis, because the removed group is coded as -1 in line with the effect coding rules; the data of the removed group is still included in the data analysis. The following section introduces how this study conducted effect coding for the categorical variable comprising four levels.

Administer effect coding in the study. Based on the effect coding rules, if an observation is a member of a given group, then the given group is coded as 1; if the observation is a member of a removed group, then the removed group is coded as -1; the groups that are neither a given group nor a removed group are coded as 0 (Pedhazur, 1982). Only one of the four research groups was observed each time and one fixed group was coded as a removed group, thus the study generated three effect variables as follows:

- E_1: effect variable for research group 1 (i.e., segmentation group)
- E_2: effect variable for research group 2 (i.e., self-explanation group)
- E_3: effect variable for research group 3 (i.e., the combination group)
- The removed group: the control group.

The following Table 11 illustrated the set of effect variables for different groups used as predictors of the multiple linear regression model introduced in the above section.

Table 11.

An Illustration of the Effect Coding Approach in this Study

Student ID	**E_1**	**E_2**	**E_3**	**Research Group**
1	1	0	0	1
2	1	0	0	1
3	0	1	0	2
4	0	1	0	2
5	0	0	1	3
6	0	0	1	3
7	-1	-1	-1	4
8	-1	-1	-1	4

Regarding the value of b_1, b_2, b_3, the regression analysis would produce their values in the outputs. To get the coefficient of the removed group that was coded as -1, the following formula was used to calculate its coefficient (Pedhazur, 1982):

$$b_4 = -(b_1 + b_2 + b_3)$$

To get the group mean of the removed group, on the following formula was used to calculate, where *a* in the grand mean (Pedhazur, 1982):

$$M_4 = a + b_4$$

Multiple Linear Regression

This study would carry out a multiple linear regression (MLR) analysis to examine how well video instruction and prior knowledge predicted cognitive load and learning achievement separately. The MLR methodology is a more superior analysis method than a paired sample *t* test. A paired sample *t* test is a methodology used to compare two means based on data collected from the same people measured at different time periods (e.g., pretest, posttest) ("Paired Sample T-Test," 2019). However, this study would like to examine whether the mean difference among four groups is zero after controlling for prior knowledge, so paired sample t-test could not satisfy the analytical needs of the study.

Also, the MLR methodology is more superior than the analysis of covariance (ANCOVA) when independent variables include both a categorical variable and a continuous variable from the analytical and conceptual perspectives (Rutherford, 2001). On the analytical level, ANCOVA is limited to categorical independent variables, but MLR accommodates various types of independent variables; on the conceptual level, the MLR methodology views all variables, either categorical or continuous, from the same frame of reference when they are working as predictors to explain a dependent variable (Rutherford, 2001). Moreover, MLR is a more robust method than ANCOVA (Rutherford, 2000) because an MLR approach could examine the proportion of variation (R^2) in the dependent variable explained by different predictors. Using the MLR methodology, this study could also test the results of statistical significance so that we could state whether the regression of video instruction on cognitive load and learning achievement was statistically significant when controlling for prior knowledge. Using MLR, this study could determine the relative importance of predictors of video instruction and prior knowledge in explaining cognitive load and learning achievement.

Multiple regression equation of the study. Regression analyses were conducted with predictors of four different types of video instruction and prior knowledge for cognitive load and learning achievement separately. The equation was as follows.

$$Y' = a + b_1X + b_2E_1 + b_3E_2 + b_4E_3 + b_5XE_1 + b_6XE_2 + b_7XE_3$$

where Y was a dependent variable (e.g., one type of cognitive load, one learning achievement aspect), Y' meant the expected value of the dependent variable, a was the intercept of the regression, X was the covariate, b_1 was the slopes or coefficient of the covariate, E_1, E_2, and E_3 were the effect variables of video instruction adopting segmentation and/or self-explanation designs respectively. b_2, b_3, and b_4 were the slopes or coefficients of the effect variables of video instruction adopting segmentation and/or self-explanation designs respectively, XE_1, XE_2, and XE_3 were the products of X and E_1, E_2, and E_3 *respectively*, representing the interaction between the covariate and the effect variables of video instruction, b_5, b_6, and b_7 were the coefficients of the interaction terms. This regression full model comprised the following three models:

Model 1： $Y' = a + b_1X$

Model 1 was a simple linear regression of cognitive load and learning achievement on prior knowledge. This regression model was to analyze the relationship between prior knowledge and cognitive load and learning achievement. Through running this regression analysis, this study could get the proportion of variance in the dependent variables explained by prior knowledge and know how well prior knowledge affected dependent variables. Also, this regression model could examine whether or not the effects of prior knowledge on cognitive load and learning achievement was not statistically significant.

Model 2 (without interaction): $Y' = a + b_1X + b_2E_1 + b_3E_2 + b_4E_3$

Model 2 was a multiple linear regression of cognitive load and achievement on predictors of prior knowledge and video instruction. Compared to model 1, this regression model added prior knowledge as a covariate. Through running this regression analysis, this study could get the results as follows: (1) examining the proportion of variance in cognitive load and learning achievement explained by prior knowledge and video instruction separately, (2) testing whether or not effects of the video instruction on cognitive load and learning achievement were statistically significant by controlling for prior knowledge, regardless of how well students' prior knowledge bases were at the beginning of the study, and (3) determining the relative importance of predictors of video instruction and prior knowledge on cognitive load and learning achievement.

Model 3(with interaction): $Y' = a + b_1X + b_2E_1 + b_3E_2 + b_4E_3 + b_5XE_1 + b_6XE_2 + b_7XE_3$

Model 3 was a multiple linear regression of cognitive load and achievement on predictors of prior knowledge, video instruction, and the interactions between prior knowledge and video instruction. Compared to model 2, this regression model added the interaction terms between prior knowledge and different types of video instruction design on the data analysis.

Through running the regression analyses, this study could get the outputs as follows: (1) examining the proportion of variance in cognitive load and learning achievement explained by a different predictor, (2) examining how well the interaction terms predicted cognitive load and learning achievement, (3) determining whether or not this study should include interaction terms into the regression analysis based on its significance on cognitive load and learning achievement.

The test of the significance of the interactions is equivalent to the test of homogeneity of regression coefficients, determining whether or not the regression lines for each research group have the same slope. If the *F* change statistics are not significant ($p < .05$), we can assume that prior knowledge affects each group the same (i.e., no interactions are presented between prior knowledge and cognitive load and learning achievement).

Based on the test results of the homogeneity of regression coefficients, this study would determine the following method for further data analyses. There are two method options: (1) an attribute-treatment interaction (ATI) method, and (2) an ANCOVA method. The study would use ATI when the effects of the interactions were significant; otherwise, the study would use ANCOVA.

Descriptive Statistics

Descriptive statistics analyses would be conducted to produce the group means, and standard deviations of participants' responses in the pretest, posttest, and cognitive load survey by group. The dependent variables that would be analyzed using descriptive statistics include: (1) intrinsic load ratings, extraneous load ratings, and germane load ratings in the cognitive load survey, and (2) professional scores, evaluative ability scores, and the overall learning performance scores the posttest.

Because the video instruction is a categorical variable divided to four levels—control, segmentation, self-explanation, and combined, the present study used the effect coding method that coded the categorical variable to be several continuous variables. The following section introduces how the present study conducted the effect coding

Pearson Correlations

Pearson correlation coefficients, *r*, were calculated to assess the relationship between posttest scores and each of the following: pretest scores and the overall cognitive load. The range of *r* took a value from -1.0 to 1.0. The results mainly looked for *r* value and *p*-value to determine the strength and direction of linear association between two variables and answer the fourth research question.

Pilot Study

The research design of this study was informed by a pilot study. The pilot study for this research was conducted at the end of the spring and summer semesters of 2018 successively. The purpose of the pilot study was to obtain initial ideas about how students respond to video modeling instructions, reveal any issues with the research design, and test and refine the data collection instruments.

Participants in the pilot study were undergraduates enrolled in six sections of the same technology integration course in which the main study is to be implemented. Four of the six sections were face-to-face classes given in the spring semester, and two sections were online classes given in the summer semester. Each section was randomly assigned to one of the four research conditions previously explained. Eighty-nine students consented to participate in the study, and seventy-two of them completed all four surveys. Only data from participants who completed all four surveys was treated as valid.

The researcher created a specific document for each research group. The document listed all procedures that participants were required to follow during this study and embedded links to a designated website-based video modeling instruction module and corresponding electronic surveys for each research group (see Appendix C). The document was published by the instructors on their course website. Students logged into the website to participate in the study after they had signed a consent form.

All participants spent no more than 50 minutes completing a video modeling instruction module and completing all surveys. The researcher observed the study in three sections and talked to several participants after they had completed the study. The main purposes of the discussions were to evaluate participants' experience with the video modeling instruction module and pre- and post-test design, and to collect information on how to improve the design of the instruction and pre- and post-test.

The results of the pilot study were used to adjust and modify the main study. One adjustment is to modify pre- and post-test survey design. The answer choices have been shortened in expression, and part two of the case study was changed from a multiple-answer format to a single-answer format. These adjustments were made based on talks with students and the researcher's assessment of initial findings from students' performance on the tests. The second adjustment is to modify the cognitive load survey questionnaire. Cronbach's coefficient alpha was .837 for the cognitive load questionnaire based on the participants in this study. However, more items will be added into the questionnaire to ensure that all items of the original instrument will be used in this study for a more comprehensive investigation of design effects on cognitive load. The third adjustment was to improve the design of the self-explaining prompts. The pilot study used only the open-ended self-explanation question format. The main study will use both the open-ended self-explanation format and the focused self-explanation format that will facilitate students to compare and contrast the received information during the learning process; and the open-ended self-explanation questions have been modified in expression in order to better direct students' attention to critical information. The fourth adjustment is to add several open-ended questions at the end of the cognitive load survey to gather information supplementing the survey findings. Moreover, this study may not be suitable for a 4 (video instructional methods) x 2 (gender) factorial design because it was difficult to identify the within-group factor in terms of gender in the pilot study. There were disproportionately more females than males.

CHAPTER 4

RESULTS

The primary purpose of this study was to examine the effects of video modeling instruction that adopts multimedia learning design principles of segmentation and self-explanation on students' cognitive load and learning achievement with covarying students' prior knowledge. The independent categorical variable of the study was video modeling instruction, which was divided into four types of methods based on the use of segmentation and self-explanation principles. The four methods were (1) an instructional method that adopted neither the segmentation principle nor provision of self-explanation questions (briefly called a control method), (2) an instructional method that adopted video segmentation by subdividing the whole video into six segments (briefly called a segmentation method), (3) an instructional method that provided seven self-explanation questions by spatially placing them before the video but did not adopt the segmentation principle (briefly called a self-explanation method), and (4) an instructional method that adopted both the segmentation principle by subdividing the whole video into six segments, and the self-explanation principle where each segmented video was paired with one or two self-explanation questions that were spatially placed before the segmented video (briefly called a combination method).

There were two main continuous dependent variables in the study—cognitive load and learning achievement. Furthermore, the types of cognitive load were divided into (1) intrinsic load, (2) extraneous load, and (3) germane load. Students' learning achievement was examined from three aspects, including (1) professional knowledge, (2) evaluative ability, and (3) the overall performance. The covariate—students' prior knowledge—was a continuous variable and obtained from students' overall scores in the pretest. This study also explored the relationship between prior knowledge, different types of cognitive load, and different aspects of learning achievement.

Analysis of Data

Participants

This study was conducted in an undergraduate-level technology integration course for preservice teachers in the early spring semester 2019 at a large public university in the southeastern United States. One hundred and twenty-one undergraduate students voluntarily participated in the study from the beginning to the end (without late arrival), followed the study instructions during the study, and completed all tasks. These undergraduates comprised 33 students in the control group (i.e., neither methods), 30 students in the experiment group 1 (i.e., segmentation), 30 students in the experiment group 2 (i.e., self-explanation), and 28 students in the experiment group 3 (i.e., combination). According to the research design, these undergraduates took a pretest, viewed a whole video or six segmented videos, took a posttest, and completed a cognitive load survey. All tests and surveys were created using Qualtrics—an online survey platform.

Conducting Power Analysis of the Sample Size

Software program G*Power 3.1 (Faul, Erdfelder, Buncher, & Lang, 2009) provides a prior analysis tool for the necessary sample size for a study. After inputting F tests, selecting linear multiple regression as the statistical test, inputting a medium estimated effect size (.5), α error (.05), a predicated power size (.80), and predictors (2), the researcher estimated that a total sample size of at least 23 participants was required for the study, with at least 6 participants for each research group. In an education study that compares different educational interventions, effect size represents the magnitude of the difference between groups (Sullivan & Feinn, 2012). The predicated power size was determined based on the level of Type II error that a researcher is willing to tolerate, and power of .80 is a reasonable target (Keppel & Wickens, 2004). Figure 10 illustrates the power analysis conducted to get this estimate.

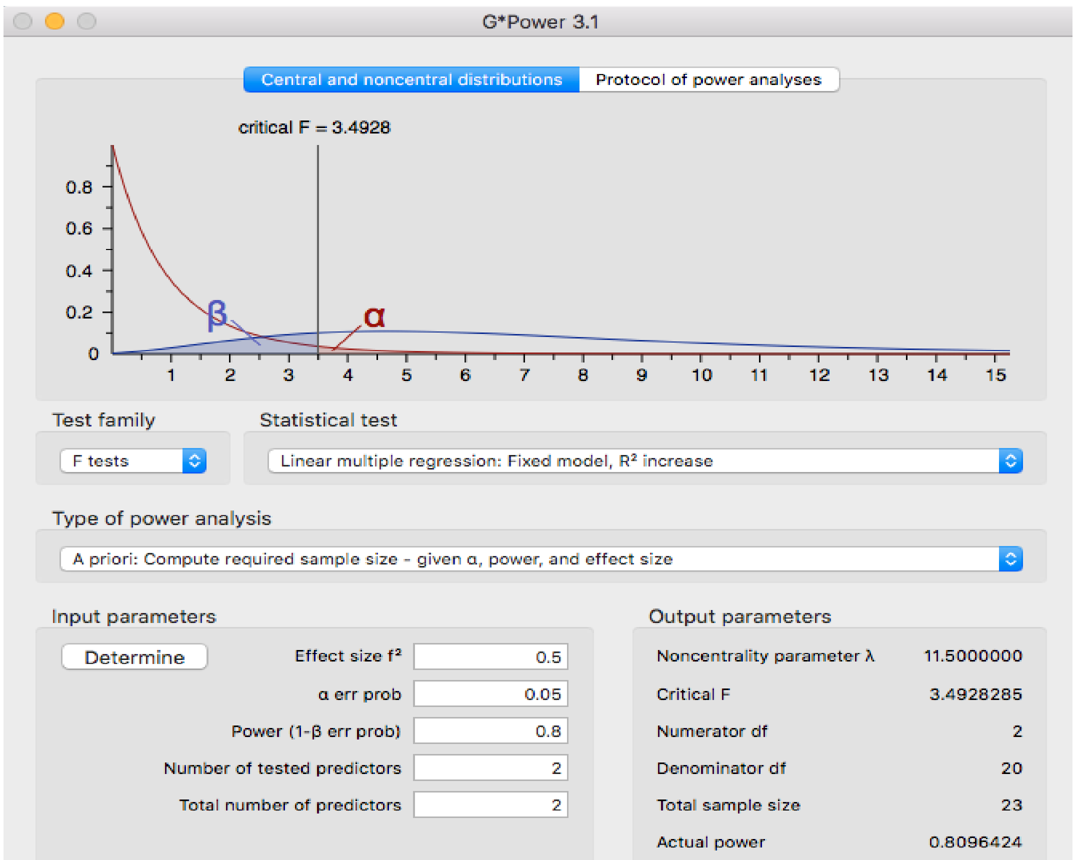


Figure 12. Power analysis output for linear multiple regression from G*Power

The researcher also administered a power analysis for a paired sample *t*-test, inputting a medium estimated effect size (.5), α error (.05), a predicated power size (.80), prescribed that each research group was assigned at least 27 participants. Thus, the participants could satisfy the requirements for a linear multiple regression analysis and a paired sample *t*-test.

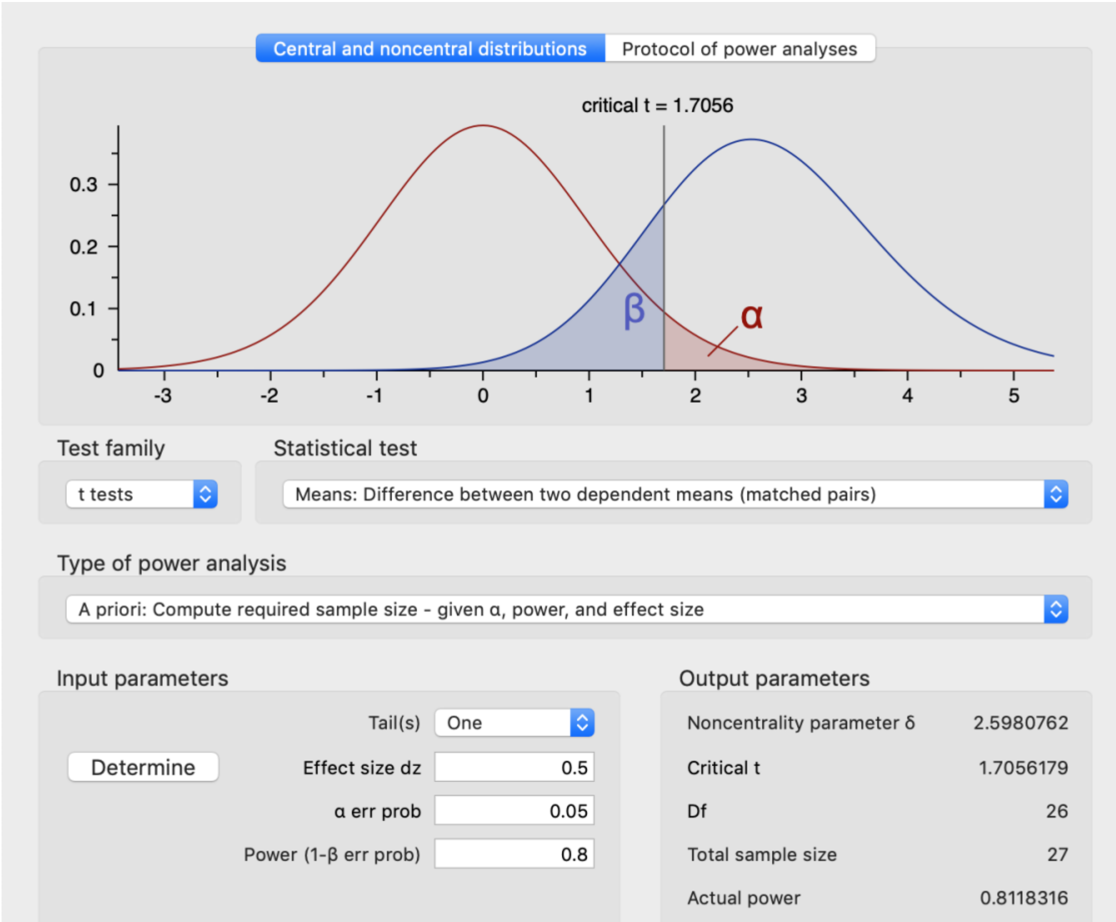


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Figure 13. Power analysis output for a paired sample t-test from G*Power

Students' Demographic Data Analysis

Table 12 presents the frequencies of the demographic data of those undergraduates whose responses were used in the study after the two rounds of data screening. These undergraduates ranged from the first year to the fifth year, including 22 first-years, 29 second-years, 18 third-years, 14 fourth-years, and three fifth-years; three students did not indicate their grade years. Among them, 89 were female, 32 were male.

Table 12

Participants' Demographic Information

		All participants	Control Group (Neither)	Experiment Group 1 (Segmentation)	Experiment Group 2 (Self-explanation)	Experiment Group 3 (Combination)
Gender	Female	89	24	22	22	19
	Male	32	9	8	8	3
Year	First	22	5	6	6	5
	Second	45	14	23	13	5
	Third	26	9	7	2	8
	Fourth	25	4	4	7	10
	Fifth	3	1	0	2	0
Major	Education	51	16	13	14	8
	Non-education	70	17	17	16	20

Students' Prior Knowledge Base Analysis

Table 13 presents students' prior knowledge base for each research group. The prior knowledge data was obtained from students' overall scores in the pretest. The results show that students in the *experiment group 3* (i.e., combination) had the highest level of prior knowledge base with the overall score (M = 6.04, SD = 1.82), which was composed of professional knowledge (M = 3.75, SD = 1.21) and evaluative ability (M = 2.29, SD = 0.98). Students in the *experiment group 2 (*i.e., *self-explanation)* had the second-best prior knowledge base with the overall score (M =5.63, SD = 1.94), which was composed of professional knowledge (M = 3.67, SD = 1.18) and evaluative ability (M = 1.97, SD = 1.10). Students in *the control group (*i.e., *neither)* had the third-best prior knowledge base with the overall score (M = 5.48, SD = 2.08), which was composed of professional knowledge (M = 3.55, SD = 1.37) and evaluative ability (M = 1.94, SD = 1.03). While, students in the *experimental group 1 (*i.e., *segmentation)* had the weakest prior knowledge base that included the overall score (M = 5.37, SD = 2.04), professional knowledge (M = 3.33, SD = 1.40) and evaluative ability (M = 2.03, SD = 1.25). However, there were no significant statistical differenced identified among the four groups regarding the overall scores (F = .629, *p* = .598), professional knowledge (F =.572, *p* = .634), and evaluative ability (F = .608, *p* = .611).

Table 13

Means and Standard Deviations of Students' Prior Knowledge

Dependent Variables	**Control**			**Segmentation**			**Self-explanation**			**Combination**			**Comparison of Means**
	M	SD	N	M	SD	N	M	SD	N	M	SD	N	
Overall	5.48	2.08	33	5.37	2.04	30	5.63	1.94	30	6.04	1.82	28	(D)>(C)>(A)>(B)
Knowledge	3.55	1.37	33	3.33	1.40	30	3.67	1.18	30	3.75	1.21	28	(D)>(C)>(A)>(B)
Evaluation	1.94	1.03	33	2.03	1.25	30	1.97	1.10	30	2.29	0.98	28	(D)>(B)>(C)>(A)

Research Question 1. What are the effects of segmentation and self-explanation on students' cognitive load when incorporating prior knowledge into consideration?

The first research question sought to examine how the four different video instruction methods would impact students' cognitive load by covarying students' prior knowledge. This study examined cognitive load from three categories—intrinsic load, extraneous load, and germane load. Multiple linear regressions were developed and administered to the effects of video instruction on cognitive load after covarying prior knowledge. A post-hoc test was conducted by using a Sidak method. The following sections provided a detailed introduction for procedures of data analyses, which was followed by a summary of analytical results. First, the study presented the means and standard deviations of the different types of cognitive load reported by each group (see Table 14).

Table 14

Means and Standard Deviations of Cognitive Load by Group

Types of Cognitive Load	Video Modeling Instructional Methods												
	Control Group (Neither)			**Experiment Group 1 (Segmentation)**			**Experiment Group 2 (Self-explanation)**			**Experiment Group 3 (Combination)**			**Comparison of Means**
	M	SD	N	M	SD	N	M	SD	N	M	SD	N	
Intrinsic[a]	9.76	4.36	33	9.57	3.89	30	9.13	4.26	30	11.29	4.93	28	(D)>(A)>(B)>(C)
Extraneous[b]	4.52	2.05	33	5.37	2.57	30	4.00	1.72	30	4.89	2.99	28	(B)>(D)>(A)>(C)
Germane[c]	22.42	3.10	33	20.13	3.86	30	22.43	3.53	30	21.96	3.67	28	(C)>(A)>(D)>(B)

a. the maximum score is 21 points.
b. the maximum score is 14 points.
c. the maximum score is 28 points.

Regarding intrinsic load, students in the experiment group 3 (i.e., combination) reported the largest load, M = 11.29 (SD = 4.93), students in the control group (i.e., neither) reported the second largest load, M = 9.76 (SD = 4.36), students in the experiment group 1 (i.e., segmentation group) reported the third largest load, M = 9.57 (SD = 389), while students in the experiment group 2 (i.e., self-explanation) reported the smallest load, M = 9.13 (SD = 4.26).

Regarding extraneous load, students in the control group (i.e., neither) reported the largest load, M = 4.52 (SD = 3.53), experiment group 2 students (i.e., self-explanation) reported the second largest load, M = 5.37 (SD =2.57), students in the experiment group 3 (i.e., combination) reported the third largest load, M = 4.89 (SD = 2.99), while students in the experiment group 2 (i.e., self-explanation) reported the smallest load, M = 4.00 (SD = 1.72).

Regarding germane load, students in the experiment group 2 (i.e., self-explanation) reported the largest load, M = 22.43 (SD = 3.10), students in the control group reported the second largest load, M = 22.42 (SD = 3.10), students in the experiment group 3 (i.e., combination) reported the third largest load, M = 21.96 (SD = 3.67), while students in the experiment group 1 (i.e., segmentation) reported the smallest load, M = 20.13 (SD = 3.86).

Developing a regression model. To examine whether there existed statistically significant differences between different group means after covarying the prior knowledge base, this study created a multiple linear regression model for data analyses. The regression model is as follows:

$$Y' = a + b_1X + b_2E_1 + b_3E_2 + b_4E_3 + b_5X E_1 + b_6X E_2 + b_7X E_2$$

where Y is intrinsic load, extraneous load, and germane load respectively, Y' means the expected value of these different types of cognitive load. X refers to the covariate, prior knowledge. E_1, E_2, and E_3 refers to the effected coded experimental groups 1, 2, 3 respectively, with the control group as the removed group. b_1, b_2, b_3, b_4, b_5, b_6, and b_7 refer to slopes or coefficients associated with the covariate, three effected coded instructional methods, and the interaction terms between the prior knowledge and three effect variables respectively. The full regression model was composed of the following three models, and the explanation of the three models refers to Chapter 3.

Model 1. $Y' = a + b_1X$

Model 2. $Y' = a + b_1X + b_2E_1 + b_3E_2 + b_4E_3$

Model 3. $Y' = a + b_1X + b_2E_1 + b_3E_2 + b_4E_3 + b_5X E_1 + b_6X E_2 + b_7X E_2$

Testing the effects of prior knowledge on cognitive load. This study first examined the effects of prior knowledge on cognitive load. Table 15 showed the outputs of the regression analyses. The outputs in model 1 regression showed the variation in a different type of cognitive load explained by prior knowledge and the results of *F* tests.

Regarding the variation in the intrinsic load, prior knowledge explained a very small proportion, R^2 = .000, and F (1, 119) = .011, p =. 918. Thus, the effect of prior knowledge on intrinsic load was not significant.

Regarding the variation in the extraneous load, prior knowledge explained .035 (R^2 = .035), a small proportion, but F (1, 119) = 4.328, p = .040. Thus, the effect of prior knowledge on extraneous load was statistically significant.

Regarding the variation in germane load, prior knowledge explained .045 (R^2 = .045), a small proportion, but F (1, 119) = 5.561, p = .020. The effect of prior knowledge on germane load was statistically significant. Thus, it was meaningful that this study included prior knowledge as a covariate when analyzing the effects of video instruction on extraneous load and germane load.

Table 15

Model Summary of Regression of Cognitive Load on Prior Knowledge, Instructional Interventions, and Their Interactions

						Change Statistics				
Dependent Variables	**Model**	**R**	**R^2**	**Adjusted R^2**	**Std. Error of the Estimate**	**R^2 Change**	**F Change**	**df1**	**df2**	**Sig. F Change**
Intrinsic Load	1	.009[a]	.000	-.008	4.400	.000	.011	1	119	.918
	2	.181[b]	.033	-.001	4.383	.033	1.308	3	116	.275
	3	.264[c]	.070	.012	4.355	.037	1.490	3	113	.221
Extraneous Load	1	.187[a]	.035	.027	2.352	.035	4.328	1	119	.040
	2	.280[b]	.078	.047	2.328	.043	1.816	3	116	.148
	3	.306[c]	.094	.038	2.339	.015	.638	3	113	.592
Germane Load	1	.211[a]	.045	.037	3.553	.045	5.561	1	119	.020
	2	.330[b]	.109	.078	3.476	.064	2.776	3	116	.044
	3	.371[c]	.138	.084	3.464	.029	1.266	3	113	.290

a. Predictors: (Constant), X

b. Predictors: (Constant), X, E_1, E_2, E_3 (without interaction)

c. Predictors: (Constant), X, E_1, E_2, E_3, XE_1, XE_2, XE_3 (with interaction)

Effects of video instruction on intrinsic load with a covariate. This study then examined the effects of video instruction on cognitive load by controlling for prior knowledge. In the above Table 15, the outputs of model 2 showed the variation in a different type of cognitive load explained by video instruction and the results of *F* tests. The study noticed that the variation in intrinsic load explained by video was small, R^2 change = .033, and *F change* (3, 116) = 1.308, $p > .05$. Thus, the effect of video instruction on intrinsic load was statistically insignificant.

Effects of video instruction on intrinsic load without a covariate. Because the influence of prior knowledge on intrinsic load was very weak, this study used ANOVA to analyze the effect of video instruction on intrinsic load without controlling for prior knowledge. To examine whether or not ANOVA was legitimated for this study, the study conducted a Levene's test to examine the equality of variances among the four research groups. Table 16 showed the Levene's test result, $p = .332$. Thus, the study legitimated to use ANOVA to analyze the effects of video instruction on intrinsic load.

Table 16

Test of Homogeneity of Variances

	Levene Statistic	**df1**	**df2**	**Sig.**
Intrinsic load	1.151	3	117	.332

The below Table 17 shows the test results of ANOVA regarding the effects of video instruction on intrinsic load without covarying prior knowledge, $F(3,117) = 1.319$, $p = .21$. The effect of video instruction on intrinsic load was still statistically insignificant without covarying prior knowledge. Thus, the study found that the effect of video instruction on intrinsic load was not significant with covarying or without covarying prior knowledge.

Table 17

Results of ANOVA of Video Instruction on Intrinsic Load

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	75.392	3	25.131	1.319	.271
Within Groups	2228.608	117	19.048		
Total	2304.000	120			

Dependent variable: Intrinsic load

Effects of video instruction on extraneous load and germane load. Because the effects of prior knowledge on extraneous load and germane load were examined to be significant, this study would continue to use the multiple linear regression methodology for further data analyses. The first step was to examine the effects of interaction between prior knowledge and video instruction. To examine the significance of the interactions, this study tested the homogeneity of regression coefficients by examining R^2 change and the F statistics in the outputs of the model 3 regression.

Test the significance of interactions. The test of significance of interactions between prior knowledge and video instruction on cognitive load is equivalent to the test of the homogeneity of regression coefficients. The F ratio for the test of the homogeneity of regression coefficients refers to the F ratio change from model 2 to model 3. Based on the outputs on the above Table 15, the homogeneity test results revealed that: for extraneous load, Fchange (3, 113) = .638, p = .592; for germane load, Fchange (3, 113) = 1.266, p = .290. Thus, the effects of the interaction terms on both extraneous load and germane load were not significant statistically. Also, the interaction terms explained a very small proportion of variation in extraneous load (R^2 change = .015) and in germane load (R^2 change = .029). Therefore, this study would use an

ANCOVA method that did not include the interactions into the data analyses by examining the outputs in model 2 (without interaction).

Effects of video instruction by controlling for prior knowledge. By controlling for prior knowledge, this study could examine the effects of video instruction on cognitive load, regardless how good participants' prior knowledge bases were. To examine the effects of video instruction on extraneous load and germane load, this study examined the statistics including the F ratio change and R^2 change from model 1 to model 2 based on the outputs in the above Table 15. The study had the following findings.

Regarding extraneous load, F ratio change from model 1 to model 2 is: Fchange(3, 116) = 1.816, R^2 change= 0.043, p = .148. Thus, the effects of video instruction on extraneous load were not statistically significant after controlling for prior knowledge.

Regarding germane load, F ratio change from model 1 to model 2 is: Fchange(3, 116) = 2.776, R^2 change = 0.064, p = .044. Thus, the effects of video instruction on germane load were statistically significant after controlling for prior knowledge, and there might exist significant group mean difference among different video instruction methods. In the next step, this study would run a post hoc test to identify which group means were different using a Sidak method.

Sidak post hoc test. The study used a Sidak method to conduct a post hoc test to identify which group means differences regarding the germane load. The reason to use a Sidak in the present study was that the SPSS only provided three options for conducting a post hoc test for ANCOVA: Fisher's Least Significant Difference (LSD), Sidak, and Bonferroni, and the Sidak method was more restrictive than the LSD method and a little less conservative than the Bonferroni method.

Fisher's LSD's procedures are powerful in controlling the familywise Type I error probabilities that do not exceed the nominal a level when means are three; however, the error rate jumps to .1222 when the means are four (Hayter, 1986; Levin, Serlin, & Seaman, 1994). Thus, the LSD's procedures are too liberal to be used in the present study.

Bonferroni's procedures are very conservative that control the family error rate using α/g level of significance, where g is the number of pairwise comparisons ("Multiple comparisons," 2018; "Post-hoc definition and types of post hoc tests," 2015). The Bonferroni method runs multiple comparison post hoc correction ("Post-hoc definition and types of post hoc tests," 2015); for example, if the present study runs four times simultaneous tests at $\alpha = .05$, the correction would be 0.05/4 = 0.0125. Thus, the LSD's procedures are too conservative to be used in the present study.

Because pairwise multiple comparison tests would be administered during a post hoc test, a Sidak method could control the family error rate using $\alpha_{SID} = 1 – (1 – a)1/k$ level of significance, where k refers to the number of pairwise comparisons (MacDonald & Gardner, 2000). For example, if the study runs four times simultaneous tests at $\alpha = .05$, the correction would be 0.0127. Sidak 's procedure is conservative because Sidak's procedure corrects alpha for all pair-wise or simple comparisons of means, but also for all complex comparisons of means as well.

The below Table 18 shows the descriptive statistics of germane load related to different instructional methods. The means of the four groups ranged from 20.13 to 22.43.

Table 18

Descriptive Statistics of Germane Load

Group	**Mean**	**SD**	**N**
Control	22.42	3.103	33
Segmentation	20.13	3.857	30

Self-explanation	22.43	3.530	30
Combination	21.96	3.666	28

Table 19 shows the outputs of a Sidak post hoc test. As is revealed in the outputs, there was no difference identified between any group means, as the *p*-values of the pairwise comparisons were bigger than .05.

Table 19

Outputs of Pairwise Comparisons Regarding the Germane Load Using a Sidak Method

					95% Confidence Interval for Difference[b]	
(I) Group	**(J) Group**	**Mean Difference (I-J)**	**Std. Error**	**Sig.[b]**	**Lower Bound**	**Upper Bound**
Control	Segmentation	2.247	.877	.068	-.100	4.595
	Self-explanation	.046	.877	1.000	-2.302	2.394
	Combination	.663	.898	.976	-1.740	3.066
Segmentation	Control	-2.247	.877	.068	-4.595	.100
	Self-explanation	-2.202	.899	.091	-4.607	.204
	Combination	-1.584	.920	.423	-4.047	.878
Self-explanation	Control	-.046	.877	1.000	-2.394	2.302
	Segmentation	2.202	.899	.091	-.204	4.607
	Combination	.617	.916	.985	-1.834	3.069
Combination	Control	-.663	.898	.976	-3.066	1.740
	Segmentation	1.584	.920	.423	-.878	4.047
	Self-explanation	-.617	.916	.985	-3.069	1.834

Based on the findings of above data analyses, this study did not identify any significant differences among different instructional methods regarding germane load, as *p* values for each pairwise comparisons were bigger than .05. Thus, effects of video instruction methods on different types of cognitive load were not significant.

Research Question 2. What are the effects of segmentation on cognitive load and learning achievement when incorporating prior knowledge into consideration?

The second question sought to examine how the four different video instructional methods impacted students' learning achievement by covarying students' prior knowledge. The data of learning achievement were obtained from students' responses in the posttest, and the data were divided into three categories—overall learning performance, professional knowledge, and evaluative ability. Multiple linear regressions were developed and administered to examine the effects of video modeling instruction on learning achievement. Post hoc tests were administered by using a Sidak method to examine group means differences. The following sections presented a detailed introduction of procedures of data analyses, which was followed by a summary of analytical results. First of all, the study presented the means and standard deviations of each group regarding the three categories of student learning outcomes in the posttest (see Table 20).

Table 20

Means and Standard Deviations of Students' Performance in the Posttest

	Video Modeling Instruction												
Dependent Variables	**Control Group (Neither)**			**Experiment Group 1 (Segmentation)**			**Experiment Group 2 (Self-explanation)**			**Experiment Group 3 (Combination)**			**Comparison of Means**
	M	SD	N	M	SD	N	M	SD	N	M	SD	N	
Post_Overall performanc[a]	6.55	1.50	33	7.13	1.61	30	7.10	1.63	30	7.82	1.19	28	(D)>(B)>(C)>(A)
Post_Knowledge[b]	4.09	0.98	33	3.93	1.11	30	4.07	0.91	30	4.50	0.51	28	(D)>(A)>(C)>(B)
Post_Evaluation[c]	2.45	1.00	33	3.20	1.16	30	3.03	1.07	30	3.32	0.95	28	(D)>(B)>(C)>(A)

a. The full points are 10. b. The full points are 5. c. The full points are 5.

As is shown in the above Table 20, the experiment group 3 (i.e., combination) outperformed the other three groups all of the three categories of learning achievement: for professional knowledge, M = 4.50, SD = 0.51; for evaluative ability, M = 3.32, SD = 0.95; for the overall performance, M = 7.82, SD = 1.12. The experiment group B (i.e., segmentation) outperformed the two other groups in two categories of learning achievement—evaluative ability and the overall performance: for evaluative ability, M = 3.2, SD = 1.16; for the overall performance, M = 7.13, SD = 1.16. The experiment group 2 (i.e., self-explanation) outperformed the control group in two categories of learning achievement—evaluative ability and the overall performance: for evaluative ability, M = 3.03, SD = 1.07; for the overall performance, M = 7.10, SD = 1.63. Students in the control group performed the weakest in the evaluative ability and the overall performance: M = 2.45, SD = 1.00; for the overall performance, M = 6.55, SD = 1.50. While, students in the control group performed the second best regarding professional knowledge and after the experiment group 3 (i.e., combination), M = 4.09, SD = 0.98.

Developing a regression model. To examine whether there existed statistically significant differences between different group means after covarying the prior knowledge base, this study created a multiple linear regression model for data analyses. The regression model is as follows:

$$Y' = a + b_1X + b_2E_1 + b_3E_2 + b_4E_3 + b_5XE_1 + b_6XE_2 + b_7XE_3$$

where Y is the overall performance, professional knowledge, and evaluative ability. Y' means the expected value of these dependent variables. X refers to the covariate—prior knowledge. E_1, E_2, and E_3 refers to the effected coded experimental groups 1, 2, 3 respectively, with the control group as the removed group. b_1, b_2, b_3, b_4, b_5, b_6, and b_7 refer to coefficients associated with the covariate, three effected coded instructional methods, and the interaction terms between the prior knowledge and three effect variables respectively. The full regression model was composed of the following three models, and the explanation of the three models refers to Chapter 3.

Model 1. $Y' = a + b_1X$

Model 2. $Y' = a + b_1X + b_2E_1 + b_3E_2 + b_4E_3$ (without interaction)

Model 3. $Y' = a + b_1X + b_2E_1 + b_3E_2 + b_4E_3 + b_5X E_1 + b_6X E_2 + b_7X E_2$ (with interaction)

Testing the effects of prior knowledge on cognitive load. This study first examined the effects of prior knowledge on learning achievement. The below Table 21 showed the outputs of the regression analyses. The outputs in model 1 regression showed the variation in a different aspects of learning achievement explained by prior knowledge and the results of *F* tests.

Regarding the variation in the overall performance, prior knowledge explained a proportion of .226 (R^2 =.226), and F (1, 119) = 34.789, p =.000. Also, the proportion in overall performance explained by prior knowledge was bigger than that explained by video instruction (R^2 =.062). Thus, the effect of prior knowledge on intrinsic load was statistically significant.

Regarding the variation in professional knowledge, prior knowledge explained .110 (R^2 =.110), and F (1, 119) = 14.732, p = .000. Also, the proportion in professional knowledge explained by prior knowledge was bigger than that explained by video instruction (R^2 =.034). The effect of prior knowledge on professional knowledge was statistically significant.

Regarding the variation in evaluative ability, prior knowledge explained .155 (R^2 =.155), and F (1, 119) = 21.899, p = .000. Also, the proportion in evaluative ability explained by prior knowledge was bigger than that explained by video instruction (R^2 =.086). The effects of prior knowledge on evaluative ability was significant.

Table 21

Model Summary of on Regression of Posttest Scores on Prior Knowledge, Instructional Methods, and Their Interactions

Dependent Variables	Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Change Statistics				
						R^2 Change	F Change	df1	df2	Sig. F Change
Overall Performance	1_a	.476[a]	.226	.220	1.366	.226	34.789	1	119	.000
	2_b	.537[b]	.289	.264	1.327	.062	3.390	3	116	.020
	3_c	.548[c]	.301	.257	1.333	.012	.655	3	113	.581
Professional Knowledge	1_a	.332[a]	.110	.103	.876	.110	14.732	1	119	.000
	2_b	.380[b]	.145	.115	.870	.034	1.552	3	116	.205
	3_c	.428[c]	.183	.133	.861	.039	1.785	3	113	.154
Evaluative Ability	1_a	.394[a]	.155	.148	1.004	.155	21.899	1	119	.000
	2_b	.492[b]	.242	.216	.963	.086	4.399	3	116	.006
	3_c	.496[c]	.246	.199	.973	.004	.208	3	113	.891

a. Predictors: (Constant), X

b. Predictors: (Constant), X, E_1, E_2, E_3

c. Predictors: (Constant), X, E_1, E_2, E_3, XE_1, XE_2, XE_3

Testing homogeneity of regression coefficients. Because the effects of prior knowledge on the three aspects of learning achievement were statistically significant, this study would examine the significance of the interactions between prior knowledge and video instruction. The test of significance of the interaction terms is equivalent to the test of the homogeneity of regression coefficients. The *F* ratio for the test of the homogeneity of regression coefficients refers to the *F ratio* change from model 2 to model 3. Based on the outputs in the above Table 21, the homogeneity test results revealed that: for the overall performance, F (3, 113) = 0.655, p = .581; for professional knowledge, *Fchange* (3, 113) = 1.785, p = .154; for evaluative ability, F (3, 113) = 0.208, p = .891. Thus, the effects of the interaction terms on all the aspects of learning achievement were not significant statistically. Therefore, this study would use an ANCOVA method that did not include the interactions into the data analyses by examining the outputs in model 2 (without interaction).

Effects of video instruction by controlling for prior knowledge. To examine the effects of video instruction on learning achievement by controlling for prior knowledge, this study examined the *F* ratio change and R^2 change from model 1 to model 2 based on the outputs in the above Table 20. The study had the following findings.

Regarding the variation in overall performance from model 1 to model 2, *F*change (3, 116) = 3.390, R^2 change = 0.062, *p* = .020. Thus, the effect of video instruction on the overall performance was statistically significant, and there might exist group mean differences among the four research groups.

Regarding the variation in professional knowledge from model 1 to model 2, *F*change (3, 116) = 1.552, R^2 change= .034, *p* = .205. Thus, the effect of video instruction on professional knowledge was statistically significant.

Regarding the variation in evaluative ability from model 1 to model 2, *F*change(3, 116) = 4.399, R^2 change = 0.086, p = .006. Thus, the effect of video instruction on evaluative ability was statistically significant, and there might exist group mean differences among the four research groups. The next step of the study was to run a post hoc test to identify which group means were different using a Sidak method.

Sidak post hoc test on the overall performance. The study first used a Sidak method to conduct pairwise multiple comparisons to examine which group means differ regarding the overall performance. As is shown in the below Table 22, the mean difference between the control group and the combination group was -1.079, *P* = .012, and it was significant at the alpha level of .05. But there were no significant differences identified among other research groups.

Table 22

Outputs of Pairwise Comparisons Regarding Overall Performance Using a Sidak Test

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Control	Segmentation	-.630	.335	.321	-1.526	.266
	Self-explanation	-.502	.335	.587	-1.398	.395
	Combination	-1.079*	.343	.012	-1.997	-.162
Segmentation	Control	.630	.335	.321	-.266	1.526
	Self-explanation	.128	.343	.999	-.790	1.047
	Combination	-.449	.351	.744	-1.389	.491
Self-explanation	Control	.502	.335	.587	-.395	1.398
	Segmentation	-.128	.343	.999	-1.047	.790
	Combination	-.578	.350	.472	-1.514	.358
Combination	Control	1.079*	.343	.012	.162	1.997
	Segmentation	.449	.351	.744	-.491	1.389
	Self-explanation	.578	.350	.472	-.358	1.514

*. The mean difference is significant at the alpha level of .05.

Sidak post hoc test on evaluative ability. The study first used the Sidak method to conduct pairwise multiple comparisons to examine which group means differ regarding evaluative ability. The below Table 23 shows the results of pairwise multiple comparisons of group means for *evaluative ability*. The results reveal that mean difference between the control group and the segmentation group was -0.770, P = .012, and it was significant at the alpha level of .05. Also, group means difference between the control group and the combination group was -0.751, P = .019, and it was significant at the alpha level of .05. There was no significance identified between other group means.

Table 23

Outputs of Pairwise Comparisons Regarding Evaluation Ability

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Control	Segmentation	-.770*	.243	.012	-1.421	-.120
	Self-explanation	-.547	.243	.147	-1.198	.103
	Combination	-.751*	.249	.019	-1.416	-.085
Segmentation	Control	.770*	.243	.012	.120	1.421
	Self-explanation	.223	.249	.939	-.444	.890
	Combination	.020	.255	1.000	-.662	.702
Self-explanation	Control	.547	.243	.147	-.103	1.198
	Segmentation	-.223	.249	.939	-.890	.444
	Combination	-.203	.254	.964	-.882	.476
Combination	Control	.751*	.249	.019	.085	1.416
	Segmentation	-.020	.255	1.000	-.702	.662
	Self-explanation	.203	.254	.964	-.476	.882

*. The mean difference is significant at the alpha level of .05.

Based on the results of regression analyses and post-hoc tests, the study found that students in the combination group significantly excelled their peers in the control group in overall performance and evaluative ability. Moreover, the students in the segmentation group excelled students in the control group regarding evaluative ability.

Research question 3. How does learning achievement relate to prior knowledge and cognitive load?

This research question sought to investigate the relationships between prior knowledge, cognitive load, and learning achievement in video instruction. The data analyses were conducted from the three aspects: (1) correlations between prior knowledge and cognitive load, (2) correlations between prior knowledge and learning achievement, and (3) correlations between cognitive load and learning achievement. The following Table 24 shows the outputs of

Pearson correlations (i.e., *r*). Pearson's *r* can vary in magnitude from -1 to 1, $r = 0.10$ refers to small effect size, $r = 0.30$ refers to medium effect size, and $r = 0.50$ refers to large effect size.

Table 24

Outputs of Pearson Correlations Between Prior Knowledge and Cognitive Load and Learning Achievement

	Prior knowledge	Intrinsic load	Extraneous load	Germane load	Overall performance	Knowledge	Evaluation
Prior knowledge	1	.009	-.187*	.211*	.476**	.332**	.394**
Intrinsic load		1	.111	.360**	.037	.011	.043
Extraneous load			1	-.424**	-.204*	-.150	-.163
Germane load				1	.132	.063	.134
Overall performance					1	.722**	.809**
Knowledge						1	.176
Evaluation							1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Correlations Between Prior Knowledge and Cognitive Load

As is shown in the outputs of Table 24, the association between prior knowledge and the intrinsic load was very weak, $r = .009$. However, there was a significant negative correlation between prior knowledge and extraneous load, $r = -.187$, $p < .05$. Also, there was a significant positive correlation between prior knowledge and germane load, $r = .211$, $p < .05$. Combining the results from both regression analyses and the Pearson correlations, this study found that prior knowledge did not affect intrinsic load but affected extraneous load and germane load. Also, the influence of prior knowledge on germane load was more significant than that on extraneous load.

Correlations Between Prior Knowledge and Learning Achievement

As is shown in the results of the Pearson correlation analyses, there was a significant positive correlation between prior knowledge and overall performance, $r = 0.476$, $p < .01$. The association between prior knowledge and professional knowledge was significantly positive, $r = 0.332$, $p < .01$. Also, there was a significant positive correlation between prior knowledge and evaluative ability, $r = 0.394$, $p < .01$. Combining the results from both regression analyses and the Pearson correlations, this study found that prior knowledge was a significant predicator for each aspect of learning achievement.

Correlations Between Cognitive Load and Learning Achievement

As is shown in the outputs of Table 24, the correlations between intrinsic load and learning achievement were not significant for any aspect, with all the p-values bigger than .05. Neither was for the correlation between germane load and learning achievement. However, there was a significant negative correlation between extraneous load and overall learning performance, $r = -.204$, $p < .05$.

In conclusion, the study found that prior knowledge was a significant factor for learning achievement. Also, prior knowledge was a significant predictor for extraneous load and germane load. However, cognitive load did not associate with learning achievement, except extraneous load that negatively affected student overall performance.

Research Question 4. What are students' perspectives of the segmentation and self-explanation designs used in the study?

This study administered open-ended questions at the end of the cognitive load survey to collect students' perspectives of the segmentation and self-explanation designs adopted in video instruction. The first open-ended question collected students' perspectives of the video used in the study. For the control group, 31 participants expressed that the video was "interesting," "informative," "helpful," "inspiring," "very effective," "intriguing," "great," "eye-opening," and "easy to understand" except two participants expressed different opinions regarding the video. One participant expressed that "the video was somewhat hard to follow, and I was not able to grasp all of the information. I got bored with videos very easily. Although it was an interesting video, and I was not able to pay attention because of length." A second participant expressed that "it wasn't hard to understand but it also did not teach me much besides the fact that a school in Singapore uses many different tactics so teach without just the traditional way of a monopolizing teacher." For the segmentation method, 28 out of 30 participants provided similar positive comments like those in the control method regarding the video except one participant who provided a neutral perspective by indicating that the video was interesting but not engaging. Regarding the self-explanation design, 29 out of 30 participants expressed similar positive comments like many participants in the designs mentioned above regarding the video except one participant, who did not respond. Regarding the combination design, all of the 28 participants liked the video and provided positive comments on it. Thus, 118 out of 121 participants liked the video and provided positive comments on it, no matter whether they viewed the whole video or segmented videos. The below Table 25 summarizes students' responses to the first question regarding the video.

Table 25

Summary of Participants' Perspectives of the Video

Responses	**Control**	**Segmentation**	**Self-explanation**	**Combination**	**Total**
Like	31	29	29	28	118 (97.5%)
Moderately dislike	2	1	0	0	3
No response	0	0	1	0	1

The second open-ended question collected learners' perspectives regarding the two methods of viewing a whole video and viewing segmented videos. Regarding the control group, almost the whole group of participants liked viewing the whole video mainly because "it was not difficult since it was only seven minutes long,' "[the] whole video gives an overall concept," and "it provides context on what the video is about." Just one participant liked to view segmented videos by expressing that segmented videos might have helped with organizing the topics and thoughts after viewing a video.

Regarding the segmentation group that used segmented videos, 21 out of 30 participants liked viewing the segmented videos, while nine participants perceived the way of viewing segmented videos as "choppy," "distracting," or "a little difficult."

Regarding the self-explanation group that used the whole video, 19 participants liked viewing the whole video, and 11 participants preferred viewing segmented videos.

Regarding the combination group that used segmented videos, 26 participants liked viewing the segmented videos; one liked viewing the whole video and expressed that the video play speed was "a little slow for me;" another did not give an explicit response by expressing that "I cannot get the background immediately, but the key concepts of the video."

Thus, 61 participants liked viewing the whole video, while 59 participants liked viewing segmented videos, and one did not give an explicit response based on all of the participants. However, when examining the responses based on each research group, this study noticed that the majority of participants liked the provided way of viewing the instructional video. For example, 32 participants in the control group like viewing the whole video, 21 participants in the segmentation group liked viewing the segmented videos, 19 participants liked viewing the whole video, and 26 participants liked viewing segmented videos. The below Table 26 summarized participants' perspectives on the way of viewing the video by group.

Table 26

Summary of Participants' Perspectives of The Two Ways of Viewing the Video

Responses	**Control$_a$**	**Segmentation$_b$**	**Self-explanation$_a$**	**Combination$_b$**	**Total**

Liked the whole video	32	9	19	1	61 (50.4%)
Liked the segmented videos	1	21	11	26	59 (48.8%)
Inexplicit responses	0	0	0	1	1 (0.8%)

a.Viewing the whole video. b. Viewing segmented videos

The third open-ended question collected participants' perspectives of guiding questions. Regarding the self-explanation design, one did not like to have guiding questions, but 28 participants would like to have, and one did not respond. Regarding the combination group, all of the 28 students liked to have guiding questions. Thus, 56 participants would like or liked to have guiding questions, but 30 would not or did not like to have, and one did not give an explicit response, and two did not respond. The Table 27 presented the summary of participants' perspectives of guiding questions.

Table 27

Summary of Participants' Perspectives of Having Guiding Questions

Responses	**Self-explanation**	**Combination**	**Total**
Liked	28	28	56 (96.7%)
Disliked	1	0	1
No response	1	0	1

The fourth open-ended question collected perspectives regarding the number of guiding questions from participants in the self-explanation design and the combination design. Regarding the self-explanation design, 25 participants expressed that the number of seven questions was suitable, four expressed that the number was too high and would like to have fewer, and one did not respond. Regarding the combination design, 25 participants expressed that the number was suitable, three responded that they would prefer to have fewer, and two participants did not directly respond. One participant expressed “the guiding questions are helpful, but I think some [guiding questions] go unanswered if looking for a specific answer from the video. If looking for a hypothetical answer from viewers, then they do get the listener thinking based upon the tidbits of information.” Another participant expressed “I thought there was some overlap and that I answered relatively the same on a few of them.” Thus, 50 participants accepted the number of guiding questions, but seven would like to have fewer questions; one did not respond; another did not answer the question but pointed out flaws with the question design. The below Table 28 summarized students’ responses to the fourth question.

Table 28

Summary of Participants’ Perspectives of the Number of Guiding Questions

Responses	**Self-explanation (viewing the whole video)**	**Combination (viewing segmented videos)**	**Total**
A good number	25	23	48 (82.7%)
Like fewer	4	3	7 (12.1%)
No response	1	2	3

In conclusion, the video and the self-explanation design were well received by the participants. However, there was a disagreement regarding segmentation design: two-fifths of the participants liked the design; however, three-fifths of the participants did not like it.

Summary of Results

Guided by the four research questions, Chapter 4 examined the effects of segmentation and self-explanation designs on the cognitive load and achievement gained by learners. The results of the analyses indicated the following:

1. Video instruction using segmentation and self-explanation designs did not produce significant mean differences regarding cognitive load.

2. The combination design significantly affected learning achievement regarding overall performance and evaluative ability; the segmentation design significantly affected learning achievement regarding evaluative ability.

3. Prior knowledge was a significant predictor for extraneous load and germane load but not for intrinsic load. Moreover, prior knowledge was a significant predictor for all the three aspects of learning achievement. The extraneous load significantly correlated with the overall performance.

4. Many participants did not like the segmentation design. Participants well accepted the self-explanation design.

CHAPTER 5

DISCUSSION

This study examined the effects of video modeling instruction created using multimedia learning principles—segmentation and self-explanation—on learners' cognitive load and learning achievement. Video modeling provided learners with a vicarious learning experience that allows learners to observe and imitate desired behaviors by viewing filmed or videotaped demonstrations. Segmentation and self-explanation were two multimedia learning design principles that were adopted in the study to facilitate learners' active processing of information and result in generative learning.

The segmentation principle states that segmenting instruction can decrease the intrinsic complexity of learning materials (Fiorella & Mayer, 2018; Mayer, 2014) and facilitate germane load (Clark et al., 2011; Fiorella & Mayer, 2018; Mayer, 2014). Also, numerous studies have found that individuals could learn better in video instruction when a continuous video was subdivided into smaller parts that allowed individuals learn at their own pace (Doolittle, 2010; Doolittle, Bryant, & Chittum, 2015; Hasler, Kersten, & Sweller, 2007; Mayer & Chandler, 2001; Mayer & Moreno, 2003). Adhering to the segmentation principle, this study adopted six video segments instead of a whole video in two video instructional design—the segmentation design and the combination design—and allowed learners to take instruction individually; the two designs also enabled learners to control their learning pace and fully process information of a segment before moving to the next.

The self-explanation principle states that self-explanation instruction can facilitate germane load (Sweller, 2010, 2011) because individuals learn better when prompted to make explanations to themselves regarding questions that direct their attention to critical information (Chi & Wylie, 2014; Kwon et al., 2011). Empirical studies have found that a self-explanation design could improve learning achievement such as conceptual understanding (Chi & Wylie, 2014; Kwon, Kumalasari, & Howland, 2011) and knowledge application (Chi & Wylie, 2014; Mayer et al., 2003; Yeh et al., 2010). Adhering to the self-explanation principle, this study developed two video instructional designs—the self-explanation design and the combination design—and incorporated seven self-explanation questions (i.e., guiding questions) that were placed above a video link to ensure that learners would read the questions before viewing the video. To ensure that learners would explain the questions to themselves, this study adopted the method of taking notes by printing out all of the self-explanation questions on a sheet of paper, with a paragraph space between each question.

The three-factor cognitive load survey questionnaire initially developed by Leppink et al. (2013) was adapted for this study and administered after video instruction to measure the learners' perceived intrinsic load, extraneous load, and germane load. A quiz for technology integration knowledge and evaluation developed by the researcher was administered to learners before video instruction to collect learners' prior knowledge. A posttest that was identical to the pretest was administered to learners after video instruction to collect data of learning outcomes. Because the participants' backgrounds varied, this study incorporated students' prior knowledge into the data analysis. A website-based instruction program was developed to administer the four different types of video instruction in ten sections of an undergraduate-level educational technology course.

The study first examined the effects of the two multimedia learning design principles on cognitive load. The results indicated that the two types of video instruction adopting the segmentation principle—the segmentation design and the combined design—did not lead to decreased intrinsic load and increased the germane load. Also, the two self-explanation designs—the self-explanation design, and the combined design—did not lead to increased germane load. Afterward, the study examined the effects of the two multimedia learning design principles on learning achievement from three aspects—overall performance, professional knowledge, and evaluative ability. The results indicated that the combined design significantly improved overall performance and evaluative ability, and the segmentation design significantly improved evaluative ability.

In order to examine at greater depth the effects of the two multimedia design principles, this study investigated the relationships between prior knowledge, cognitive load, and learning achievement. The results indicated that prior knowledge was negatively correlated with extraneous load but positively correlated with germane load; however, there was no significant correlation between prior knowledge and the intrinsic load. Also, prior knowledge was correlated with the three aspects of learning achievement positively. These findings were the same as those obtained from the regression analyses, indicating that prior knowledge was an important predictor for extraneous load and germane load as well as learning achievement.

The present study finally investigated participants' perspectives of different instruction methods to develop broader understandings regarding the effects of the two multimedia design principles on cognitive load and achievement. The results of the study indicated that many participants did not like the segmentation design but liked to have guiding questions.

The following sections discuss the significant findings by combining empirical studies in the literature to identify other factors that may influence the study outcomes. The following sections also addressed the contributions, limitations, and implications of the study for future research.

Effects of Prior Knowledge as a Covariate

This study found that prior knowledge was a significant predictor for the extraneous load (r = -.187, p < .05) and the germane load (r = .211, p < .05); an increase of prior knowledge could lead to a decrease of extraneous load and an increase of germane load. Also, prior knowledge was a significant predictor for learning achievement regarding overall performance (r = .476, p < .01), professional knowledge (r = .332, p < .01), and evaluative ability (r = .394, p < .01); an increase of prior knowledge could lead to an increase in different aspects of learning achievement. These findings were consistent with the proposition by Kalyuga (2005) and Yeh et al. (2010) that prior knowledge was one of the most critical learner traits that affects instruction. Thus, by controlling for prior knowledge, a regression analysis could be more powerful in examining the effects of video instruction on cognitive load and learning achievement.

However, this study found that prior knowledge was not a significant predicator for the intrinsic load. The correlation between prior knowledge and the intrinsic load was minimal, r = .009 (p < .06); the F statistics of the regression analysis also revealed that the effect of prior knowledge on the intrinsic load was not statistically significant, F (1, 119) = .011, p =. 918. These findings indicated that the participants perceived the complexity level of video topics, content, and concepts (i.e., the focuses of the three intrinsic load survey items) at a similar level. One explanation for the findings on the relationship between the intrinsic load and prior knowledge is the time to administer the study. This study was administered during the second and third week of a semester. Participants had just begun to learn theories of meaningful learning with technology and had not yet designed a technology-enhanced lesson plan when the study was conducted. The lack of professional knowledge and experience may have had a negative impact on student performance in this study. Moreover, the majority of the participants liked viewing the video and commented on the video as interesting, informative, and inspiring. So, the researcher of the study supposes that the perception of a video might offset students' perceived complexity of the video content and thus affect their ratings of the intrinsic load. Future studies are recommended to explore how videos of differing genres and design styles may lead students to perceive different intrinsic loads.

Effects of Segmentation and Self-explanation on Cognitive Load

The first research question guided the present study to examine the effects of video instruction that adopted segmentation and self-explanation designs on three types of cognitive load. This section focuses on discussing the relevant findings while analyzing the reasons for the study's outcomes. This section also provides suggestions for future research.

Effects on Intrinsic Load

This study found that there was no statistically significant mean difference regarding intrinsic load, F (3,116) = 1.308, $p > .05$. This finding indicated that the present study did not identify segmentation effects on decreasing the intrinsic load, and it was not consistent with the proposition by Doolittle et al. (2015), Fiorella and Mayer (2018), Mayer and Moreno (2003), and Mayer (2014). These scholars contended that the method of segmenting a continuous video into discrete segments was a useful technique for helping manage the intrinsic cognitive load of an instructional video by reducing the complexity of learning information. Why did segmentation ~~did~~ not produce the effect of decreasing intrinsic load in this study?

One explanation for the finding may be attributed to participants' dispositions to segmentation. This study subdivided an instructional video of 7 minutes and 34 seconds into six segments, but two-fifths of the participants responded that they did not like segmentation in the open-ended question survey. Some participants offered negative comments on segmented videos stating that they were "choppy," "distracting." The researcher supposes that participants' negative dispositions might lead them not to rate segmentation as a method of managing the intrinsic load. This finding was not consistent with the findings revealed by Doolittle et al. (2015). Doolittle et al. (2015) did not identify negative student dispositions toward non-segmentation, seven-segments, and 14-segments manipulated on a 9-minute historical instructional video except the 28-segments. Thus, future study is recommended to examine student dispositions to video segmentation in a more in-depth way.

Another possible explanation for the finding is the lack of a clearly established definition for "complexity" between the researcher and the participants. Drawing upon Sweller's (1994, 2010, 2011) element interactivity, the researcher interpreted that this video was composed of much information that required learners to combine them when evaluating teaching practices in the video. However, the researcher did not investigate students' perspectives regarding the inherent complexity of the instructional video and did not provide students with any prior training for defining a video's complexity. Thus, the standards to define the complexity of the video content might differ between the participants and the researcher.

Regarding the definition of the complexity of instructional videos, there are no specific and precise definitions in the literature. Mayer and Moreno (2003) did not offer a specific definition of "complexity" when they proposed segmenting as one of the nine ways to reduce the intrinsic load in multimedia learning. For example, Mayer and Moreno (2003) only used "conceptually complex" (p.47) to describe complicated materials that lead to the issue that the "available capacity is not sufficient to meet the required processing [cognitive] demands" (p.47). Dolittle et al. (2015) did not define the complexity of the nine-minute historical instructional videos in their study, either. Fiorella and Mayer (2018) did not define the complexity of materials when discussing the effectiveness of segmentation design. Future research is recommended to provide students with training on defining and evaluating the content complexity of videos when administering a study that examines the effects of segmentation on intrinsic load.

Effects on Extraneous Load

This study did not find statistically significant mean differences between the four research groups in extraneous load, F (3,116) = 1.816, p >.05. However, this study noticed that students in the segmentation group (i.e., viewing the segmented videos) reported the biggest mean of extraneous load among all of the groups, M = 5.37 (SD = 2.57), and only nine out of the 30 participants liked viewing the segmented videos. The second biggest group mean of extraneous load was reported by the combination group that also used segmented videos, M = 4.89 (SD = 2.99). Based on these group mean statistics and student dispositions against the segmentation design, the researcher supposes that segmentation might produce extraneous load in this study.

This study did not find self-explanation to produce extraneous load. Moreover, 56 out of 58 participants involved in the two self-explanation groups liked to have guiding questions. Kalyuga (2008) and Sweller (2006) expressed their concerns that self-explanation might engender extraneous load. Thus, this study incorporated the method of taking notes as a solution to address the concern. Based on the findings of the study, the method of taking notes might have played a role in improving the self-explanation designs in terms of preventing extraneous load.

Effects on Germane Load

This study found the significance of video instruction on germane load, F (3,116) = 2.776, p = .044; however, there was no significant mean difference revealed from the Sidak post hoc tests. These findings were not consistent with theories regarding the segmentation effects on germane load: A system-manipulated segmentation design could allow learners to fully process the information of a segment before proceeding to the next and thus promoting germane load (Clark et al., 2011; Fiorella & Mayer, 2018; Mayer, 2104). Nevertheless, the two groups using segmentation design—the segmentation group and the combined group—did not report more significant germane load.

Moreover, the findings of the study were not consistent with the self-explanation effects on promoting germane load. According to Sweller (2010) and Wylie and Chi (2014), a self-explanation design could facilitate germane load through managing distractive activities and directing learners to focus critical information and engage in active, generative information processing. However, the two groups using a self-explanation design—the self-explanation group and the combined group—did not report more significant germane load than the other two groups that did not use a self-explanation design.

Furthermore, the combination design that drew upon both a segmentation design and a self-explanation design was expected to produce more significant germane load than other instruction designs; however, the results did not reveal this effect. However, the mean score of the germane load reported by the self-explanation group was the biggest, M = 22.43 (SD = 3.53), following by the control group, M = 22.42 (SD = 3.10). The mean of germane load reported by the combination group was 21.96 (SD = 3.67).

Why did the post hoc tests not reveal significant differences in germane load? One possible reason may be attributed to the use of the Sidak method for administering the post hoc test. The multiple-comparison correction α value that the Sidak method took was 0.0127 in this study, which was a bit less conservative than the Bonferroni's correction α value of 0.0125. Bonferroni is "a conservative test, that protects form Type I error, is vulnerable to Type II errors (failing to reject the null hypothesis when you should in fact reject the null hypothesis)" ("Bonferroni Correction," 2019). Nonetheless, the SPSS only provided three options for running ANCOVA post hoc tests, including the Bonferroni method, the Sidak method, and Fisher's LSD method. Regarding Fisher's LSD method, the correction α value was .1222, which was too liberal in controlling Type I error (i.e., falsely reject the true hypothesis) in this study.

Effects of Segmentation and Self-explanation on Learning Achievement

Guided by the second research question, the present study examined the effects of video instruction adopting segmentation and self-explanation on learning achievement by covarying prior knowledge. The study found significant effects on overall performance, F (3,116) = 3.390, $p < .05$, with the mean of the combination group excelling that of the control group with 1.079 points ($p = .012$). Also, the present study found significant effects on evaluative ability, F (3,116) = 4.399, $p < .05$, with the mean of the combination group excelling that of the control group with 0.751 points ($p = .019$) and the mean of the segmentation group excelling that of the control group with 0.770 points ($p = .012$). However, the study did not find significant effects on professional knowledge.

The Segmentation Effects on Learning Achievement

Two video instruction groups using a segmentation design were identified as significant effects on evaluative ability. The segmentation effects on improving evaluative ability were consistent with learning achievement revealed by empirical studies (Doolittle et al., 2015; Kwon, Kumalasari, & Howland, 2011; Mayer & Chandler, 2001). These studies, which tested the segmentation method in multimedia learning, reported that the method of segmentation improved students' higher-level learning outcomes such as knowledge transfer and problem-solving.

However, the effects of the segmentation design on learning achievement were not as prominent as those of the combination design. First, when examining group means before controlling for prior knowledge, the combination group excelled the segmentation group in all of the three aspects: (1) regarding the overall performance, the mean of the combination group was 7.82 (SD = 1.19), while the mean of the segmentation group was 7.13 (SD = 1.61); (2) regarding the professional knowledge, the mean of the combination group was 4.50 (SD = 0.51), while the mean of the segmentation group was 3.93 (SD = 1.11); and (3) regarding evaluative ability, the mean of the combination group was 3.32 (SD = 0.95), while the mean of the segmentation group was 3.20 (SD = 1.16). Then, when examining the outputs of the Sidak post hoc test, the combination group excelled the control group in both the overall performance (P = .012) and evaluative ability (P = .019); however, the segmentation group simply excelled the control group in evaluative ability (P = .012). The reason to explain the findings may be attributed to the additional self-explanation effect with the combination design.

The Self-explanation Effects on Learning Achievement

This study did not find segmentation effects on learning achievement with the self-explanation instruction but identified the effects with the combination instruction. Self-explanation was reported to improve learning achievement (Chen et al., 2010; Mayer, Dow & Mayer, 2003; Schworm & Renkl, 2006). These researchers, who tested the self-explanation method in multimedia learning, found that the method of self-explanation could improve higher-level learning outcomes such as conceptual understanding and knowledge application.

One explanation for these findings can be attributed to the segmentation effects. The self-explanation design used the whole video, while the combination design used the segmented videos. Combining segmentation with a self-explanation design in instruction produced significant effects on learning achievement.

The Combination Effects on Learning Achievement

Apart from the statistical significance regarding the combination effects on learning achievement, this study found an overall positive response to the combined design in student surveys. Twenty-six out of the 28 participants liked the segmentation design, and all of them liked the use of guiding questions during learning. According to those students, having one or two questions for each video segment is good design. Thus, the effects of combining segmentation and self-explanation designs on learning achievement have been supported by the present study and the previous studies in the literature.

Based on the identified effects on learning achievement, the present study suggests that the combination design is a constructive feature (Kurz & Batarelo, 2010) that supports student success in video instruction. On the one hand, the segmentation method restructured the presentation format of video to enable learners to effectively control the learning pace for searching and selecting critical information. On the other hand, the self-explanation method addressed the problem that students did not know what to look for while viewing a video model (Kurz & Batarelo, 2010) and facilitated students to become active thinkers and learners rather than passive viewers (Choi, 2014; Hassanabadi et al., 2011; Yeh, Chen, Hung, & Hwang, 2010). Guided by questions, students actively search for relevant information and take notes to respond to guiding questions. Well-designed guiding questions can also enable learners to fix misconceptions, fill in information gaps between the materials and their existing schema (Chi, 2000; Yeh et al., 2010; Wouters et al., 2007), and organize and integrate associated information to construct a coherent learning representation. Combining the segmentation and self-explanation methods facilitates learners' cognitive engagement with the learning materials, which lets them actively process the learned information. Thus, this study recommends the use of a combination method when instructors or researchers develop video instruction.

Limitations of the Study

The present study adopted an experiment design to realize a high-level of rigor and ability to generalize statistical results across populations (Dousay, 2014). However, the researcher should address several limitations. The first limitation concerns the cognitive load measure which was modified from an instrument initially developed by Leppink et al. (2013). The modified tool did not achieve excellent value for Cronbach's alpha (α=. 749). Also, an item was excluded from the factor of the extraneous cognitive load because the item dramatically dropped the Cronbach's alpha value of the factor.

The second limitation concerns the reliability of the quiz used for pre- and posttest in the study. Based on students' responses in the study, the Cronbach's alpha value of the quiz was .512, which means that inter-relatedness of the items within the quiz was not good, although acceptable (Tavakol & Dennick, 2011). Therefore, the reliability of the two measurements might have been affected accordingly.

The third limitation concerns the sample size. Although the sample size of the study met the minimum requirements during the power analysis, the statistical power of the overall number of participants (N=121) limited the ability to generalize to the larger population from which the sample was selected. Therefore, future studies are recommended to recruit a more significant number of participants.

The fourth limitation concerns the participants' various backgrounds. For this study, non-education majors comprised a more significant proportion (57.85%) of participants than education majors. However, the researcher specifically selected an instructional video for educating preservice teachers. Although this study had controlled for prior knowledge during the data analyses, this study might still suffer from the participants' academic backgrounds in the process of collecting data, especially in the self-rating cognitive load survey.

The fifth limitation concerns the design of guiding questions. Developing guiding questions is one of the most challenging jobs when preparing for the study so that the researcher invested much effort in this regard. The researcher found it confounding to distinguish different types of prompts proposed by Wylie and Chi (2014) because the literature did not provide clear definitions for different prompts. Moreover, the researcher could not find design guidelines in the literature studies that used self-explanation design in studies. Thus, there might have been flaws in designing guiding questions in this study.

Implications for Future Research and Practice

Video modeling has been increasingly applied to different learning settings, especially in online learning. Video modeling not only demonstrates the advantages of sharing knowledge and skills with numerous learners without the spatiotemporal limits of live modeling but also holds the promise of engaging students in ways that text-based modeling could never deliver

(Dosay, 2014). To develop video modeling to be an effective instructional method that facilitates active, generative learning, we need to construct interactive multimedia learning environments that can effectively engage students in active information processing and thus achieve higher-level learning outcomes. After extensively exploring cognitive load theories of multimedia learning, this study adopted two robust multimedia learning design principles—segmentation and self-explanation—in developing video modeling instruction. Based on the knowledge and findings discovered in the process of designing and administering video instruction using the two design principles, this study indicated the following implications for future research and practice.

First, using conceptual interactivity as a conceptual framework is a promising guideline to construct interactive learning environments for video modeling instruction. Although the concept of cognitive interactivity has been previously proposed and studied in a body of literature applying the concept into video modeling design is not listed as an instructional design approach (Ottenbreit-Leftwich et al., 2010). The goals of constructing cognitive interactivity were to optimize learners' cognitive engagement and maximize their learning achievement. Thus, this study provided both cognitive and metacognitive instructional scaffoldings to restructure the presentation format of instructional videos. The proposed model of constructing the learner-and-video conceptual interactivity will guide future research and practice as well as invite further discussions regarding video instruction. More importantly, the construction of the learner-and-video conceptual interactivity is open to various multimedia learning design principles as long as they are selected and tailored according to the targeted learning task and learner characteristics and can satisfy the demands of a specific learning setting.

Second, this study utilized effects on cognitive load and learning achievement as evidence to examine the quality of video instruction design. Cognitive load is a mediator between instructional design and learning achievement (Paas et al., 2003), and cognitive load theory has been used to explain a broad set of experimental findings (Jong, 2009). Thus, the findings of the study add to the knowledge base to enhance understanding of how video instruction should be designed to support the learner-and-video conceptual interactivity.

Third, this study revealed the potential of the combination design as an augmented design that can add substantial values for facilitating higher-level learning achievements. The results of the study revealed that the combination design could significantly affect both evaluative ability and the overall performance of learners in an interactive video environment. Also, the combination design was well accepted and confirmed by the participants who used the method. However, the combination method did not find evidence in terms of facilitating germane load to support its generalization across populations.

The findings of this study indicate future research directions. Future research directions may include identifying a set of mechanisms for video segmenting that is supported by learning theories and validated by learner dispositions in different settings. Also, the identification of segmenting mechanisms is recommended to distinguish their applications on different types of videos such as animation videos, interview videos, or storytelling videos. The reason for distinguishing video types is that each type of video features different formats of elements that generate different levels of element interactivity (Sweller, 1994, 2010, 2011) which is a theorical framework to define the complexity levels of instructional video. For example, animated videos are much more dynamic and image-oriented than interview videos, which means that the element interactivity of animated videos is more complicated. Thus, we need to apply different mechanisms to define element interactivity for different video types. However, current literature lacks such guidelines to distinguish element interactivity for different video types. Thus, it poses a challenge for researchers and instructional designers when segmenting videos.

Future research is also recommended to provide participants with trainings or workshops to communicate how to define and evaluate the complexity of a video used in a specific study. The goals of the training and workshops are to maximize the degree of consensus among participants and minimize the discrepancies in rating the intrinsic load of video instruction.

Furthermore, future research is recommended to more explicitly distinguish different formats and structures of self-explanation prompts. A clear definition of a type of self-explanation prompt would provide an important reference for researchers and instructional designers when designing self-explanation prompts. Moreover, future research is recommended to compare the effects of different types of self-explanation prompts on learning achievement.

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APPENDICES

Appendix A: Institute Review Board Approval

The Effects of Interactivity Design

Protocol ID#STUDY00005045

PI:	ROBERT Branch	Primary Contact:	Hua Zheng
Submission Type:	Initial Study	Detailed State:	Approved
IRB Coordinator:	Brooke Harwell	Parent Protocol:	
Review Category:	Exempt		
Approved Date:	7/21/2017	**Begin Date:**	7/21/2017
Expiration Date:	7/20/2022	**External IRB Information:**	

Appendix B: Consent Form

Dear Students:

I am a professor in the Department of Career and Information Studies at The University of Georgia. I invite you to participate in a research study entitled The Impact of Segmentation and Self-Explanation on Students' Cognitive Load and Learning Achievement Within the Context of Video Modeling. The purpose of this study is to contribute to the theory and practice of the interactivity design of multimedia learning environments by testing a set of constructs drawing upon the cognitive theory of multimedia learning. Your participation will involve completing a pretest, watching a video, taking notes while viewing the video, completing a posttest, and completing a learning engagement and cognitive load survey. Your notes will be collected and used for the study analysis but not be graded for any purpose. If you participate in this study, complete all the tests and surveys, and submit your notes, your course instructor will give you a Late Pass. The function and usage of the Late Pass is referred to the statement described in your course syllabus.

The whole research process will last approximately 55 minutes. Your involvement in the study is voluntary, and you may choose not to participate or to stop at any time without penalty or loss of benefits to which you are otherwise entitled. The decisions whether or not to participate will not influence the availability of services or evaluations (e.g., grades) that you may receive outside of the context of the research. If you decide to stop or withdraw from the study, the information/data collected from or about you up to the point of your withdrawal will be kept as part of the study and may continue to be analyzed.

The findings from this project may provide information on improve the cognitive interactivity design of multimedia learning environments. There are no known risks or discomforts associated with this research. The data will be analyzed and reported in the format of group means. Researchers will also limit the description of specific characteristics so that participants cannot be identified. Researchers will limit the description of specific characteristics so that participants cannot be identified. All data will be reported using pseudonyms or a case number such as "Participant 1," and "Participant 2." The results of the research study may be published, but your name or any identifying information will not be used. In fact, the published results will be presented in summary form only.

If you have any questions about this research project, please feel free to send an email to rbranch@uga.edu. Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board; telephone (706) 542-3199; email address irb@uga.edu.
Your signature below indicates your agreement to participate in the above project.

______________________________ ______________________________ ____________________

Name of Participant Signature of Participant Date

Thank you for your consideration! Please keep this letter for your records.

Sincerely,

Dr. Robert M. Branch

Professor & Principal Investigator

Career and Information Studies

University of Georgia

UGA E-mail: rbranch@uga.edu

Hua Zheng

Sub-investigator/student

Phone: (706)3080353

UGA E-mail: hua.zheng25@uga.edu

Career and Information Studies

University of Georgia

Appendix C: Note Sheet for Non-self-explanation Conditions

Research Group: _________Research ID: _______ UGA E-email address: ______________

Instructions: Please take some notes while your viewing the videos. The notes can help you recall your memories when answering the questions in the posttest. Your notes will not be graded for any purpose, but they will be used as evidence together with the task completion for your instructor's giving you **a Late Pass** reward.

Appendix D: Note Sheet for Self-explanation Conditions

Research Group: _________Research ID: _________ UGA E-email address: _______________

Instructions: Please take some notes while your viewing the videos. The notes can help you answer the guiding questions given in the instruction and questions in the post-test. Your notes will not be graded for any purpose but will be used as evidence together with the task completion for your instructor's giving you **a Late Pass** reward.

(Video Segment 1) Administrators emphasize technology integration in the classroom
Listen carefully to the speeches given by the school principal, education administer, and professor Kong and think about:
(1) Why should the school implement technology integration?

(2) What roles do teachers and students play in meaningful technology integration?

(Video Segment 2) A science teacher uses an instant messaging tool to teach velocity
Please **combine** the school principal's speech with the technology integration case to think about:
(3) How does using the instant messaging tool help students engage in the classroom?

(4) What is the main instructional goal that the teacher wants to develop his students in this case?

(Video Segment 3) An art teacher uses a Second Life art gallery to teach art
Please **combine** the teacher's speech with students' performance to think about:
(5) How does the teacher use a Second Life art gallery to improve students' learning involvement, as opposed to organizing a museum field trip?

(Video Segment 4) A science teacher use Facebook to teach electrons
Please **Combine** the school principal's speech and the technology integration case to think about:
(6) How does using Facebook help the teacher engage students in an academic way?

(Video Segment 5) Teachers use video modeling and online conferencing tools for professional development
(7) Why do teachers need to conduct ongoing professional development, specifically in meaningful technology integration?

Appendix E: Screenshot of the Video Modeling Instruction Module 1

Module Instructions

You will view a video that recorded how Ngee Ann Secondary School in Singapore develops and implements technology integration in the classroom. The video contents cover the leadership, teachers' professional development, and THREE instruction practices in the real classroom that emphasize the use of technology, digital media, and the integration of 21st-Century skills.

The video lasts for appropriately **7 minutes and 34 seconds** in total. **Please watch from the beginning to the end!** You feel free to pause or rewind as you like, but **skipping or fast-forwarding is not allowed** for ensuring the quality of this study. Also, please **take notes** while viewing the video as the notes are helpful for recall your memory when doing the posttest.

This video was published by Edutopia on YouTube at https://www.youtube.com/watch?v=M_pIK7ghGw4.

Learning Objectives

Through taking this video modeling instruction, you are expected to:

1. **Improve your professional knowledge** that empowers you to :

    (1) discern the right roles that teachers, students, and technology should play in meaningful technology integration practices.

    (2) develop an awareness of combining developing students' 21st Century skills into technology integration practices.

2. **Improve the evaluation ability** that empowers you to:

    (1) criticize and assess the quality of technology integration practices from broader and more comprehensive perspectives.

View the Video

Singapore's 21st-Century Teaching Strategies

Click here to view the video

(Please check whether the video is playing from the beginning before viewing! You can click "**CC**" button to get captions.)

Appendix F: Screenshot of the Video Modeling Instruction Module

Video modeling module 2:

Learning with segmented videos

Module Instructions

You will view videos that recorded how Ngee Ann Secondary School in Singapore develops and implements technology integration in the classroom. The video contents cover the leadership, teachers' professional development, and THREE instruction practices in the real classroom that emphasize the use of technology, digital media, and the integration of 21st-Century skills.

In this module, you will view **SIX** videos. These video are segments split from the same video, so they are coherent and connected in content. **Thus, you are required to all of the six videos. Please watch each video from the beginning to the end! !** You feel free to pause or rewind as you like, but **skipping or fast-forwarding is not allowed** for ensuring the quality of this study. The total video length is **7 minutes and 34 seconds**. Also, please **take notes** while viewing the video as the notes are helpful for recall your memory when doing the posttest.

This video was published by Edutopia on YouTube at https://www.youtube.com/watch?v=M_pIK7ghGw4.

Learning Objectives

Through taking this video modeling instruction, you are expected to:

1. Improve your professional knowledge that empowers you to :

(1) discern the right roles that teachers, students, and technology should play in meaningful technology integration practices.

(2) develop an awareness of combining developing students' 21st Century skills into technology integration practices.

2. **Improve the evaluation ability** that empowers you to:

(1) criticize and assess the quality of technology integration practices from global and more comprehensive perspectives.

View Videos

(Please check whether the video is playing from the very beginning before viewing! You can click "**CC**" button to get captions.)

Video Segment 1. Administrators emphasize technology integration in the classroom

Click here to view video segment 1

Video Segment 2. A science teacher uses an instant messaging tool to teach velocity

Click here to view video segment 2

Video segment 3. An art teacher uses a Second Life art gallery to teach art

Click here to view video segment 3.

Video segment 4. A science teacher uses Facebook to teach electrons

Click here to view video segment 4.

Video segment 5. Teachers use video modeling and online conferencing tools for professional development

Click here to view video segment 5

Video segment 6. Technology integration is an adaptive approach to students' changing demands

Click here to view video segment 6

Appendix G: Screenshot of the Video Modeling Instruction Module 3

Video modeling module 3:

Learning with guiding questions

Module Instructions

You will view videos that recorded how Ngee Ann Secondary School in Singapore develops and implements technology integration in the classroom. The videos cover the leadership, teachers' professional development, and THREE instruction practices in the real classroom that emphasize the use of technology, digital media, and the integration of 21st-Century skills.

In this module, you will view **SIX** videos. These video are segments split from the same video, so they are coherent and connected in content. **Thus, you are required to view all of the six videos. Please watch each video from the beginning to the end!** You can feel free to pause or rewind as you like, but either **skipping or fast-forwarding is NOT allowed** for ensuring the quality of this study. The total video length is 7 minutes and 32 seconds.

Furthermore, please **READ guiding questions** provided before each video segment. Also, please **RESPOND to the questions by taking notes** while viewing the video.

copyright of the video (s): This video was published by Edutopia on YouTube at https://www.youtube.com/watch?v=M_pIK7ghGw4.

Learning Objectives

Through following this video modeling instruction, you are expected to:

1. Improve your professional knowledge that empowers you to :

(1) discern the roles that teachers, students, and technology should play in meaningful technology integration practices.

(2) develop an awareness of combining the development of students' 21st Century skills into technology integration practices.

2. **Improve the evaluation ability** that empowers you to:

(3) criticize and assess the quality of technology integration practices from global and more comprehensive perspectives.

View Videos

(please read the following guiding questions before viewing the video! Also, take notes to answer these questions while viewing the video!)

Guiding questions:

At the beginning scenario, you will watch the school principal, education administer, and a university professor are talking. Listen carefully to their speeches and think about:

(1) Why should the school implement technology integration?

(2) What roles do teachers and students play in meaningful technology integration in the classroom?

Next, you will watch a science teacher uses an instant messaging tool to teach velocity.

Please combine the school principal's speech with the technology integration case to think about:

(3) How does using the instant messaging tool help students engage in classroom?

(4) What is the main instruction goal that the teacher wants to develop his students in this case?

Then, you will watch an art teacher uses Second Life art gallery to teach art.

Please combine the teacher's speech with students' performance to think about:

(5) How does the teacher use Second Life art gallery to improve students' learning involvement, as opposed to organizing a museum field trip?

And then, you will watch a science teacher uses Facebook to teach the electron.

Please combine the teacher's speech and students' performance to think about:

(6) How does the teacher use Facebook to engage students in an academic way?

Lastly, you will watch teachers use video modeling and online conferencing tools for professional development.

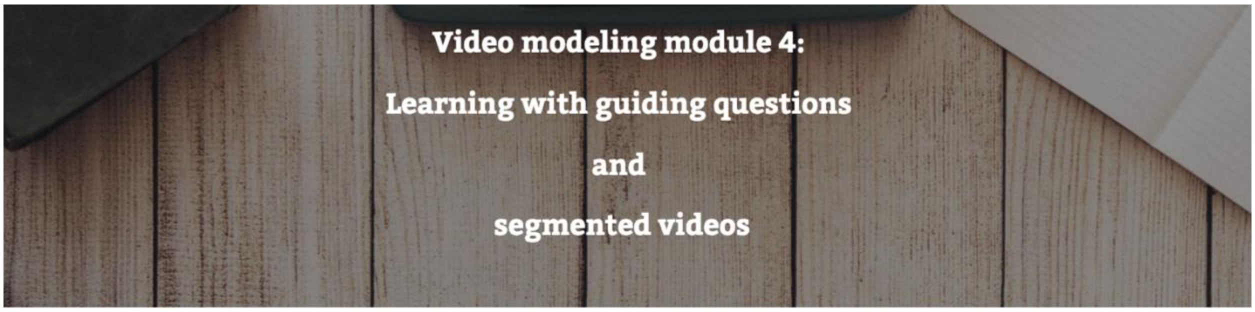
(7) Why do teachers need to conduct ongoing professional development, specifically in meaningful technology integration?

Singapore's 21st-Century Teaching Strategies

Click here to view the video

(Please check whether the video is playing from the very beginning before viewing! You can click "**CC**" button to get captions.)

Appendix H: Screenshot of the Video Modeling Instruction Module 4



Module Instructions

You will view videos that recorded how Ngee Ann Secondary School in Singapore develops and implements technology integration in the classroom. The videos cover the leadership, teachers' professional development, and THREE instruction practices in the real classroom that emphasize the use of technology, digital media, and the integration of 21st-Century skills.

In this module, you will view **SIX** videos. These video are segments split from the same video, so they are coherent and connected in content. **Thus, you are required to view all of the six videos. Please watch each video from the beginning to the end!** You can feel free to pause or rewind as you like, but either **skipping or fast-forwarding is NOT allowed** for ensuring the quality of this study. The total video length is 7 minutes and 32 seconds.

Furthermore, please **READ guiding questions** provided before each video segment. Also, please **RESPOND to the questions by taking notes** while viewing the video.

copyright of the video (s): This video was published by Edutopia on YouTube at https://www.youtube.com/watch?v=M_pIK7ghGw4.

Learning Objectives

Through following this video modeling instruction, you are expected to:

1. Improve your professional knowledge that empowers you to :

(1) discern the roles that teachers, students, and technology should play in meaningful technology integration practices.

(2) develop an awareness of combining the development of students' 21st Century skills into technology integration practices.

2. **Improve the evaluation ability** that empowers you to:

(3) criticize and assess the quality of technology integration practices from global and more comprehensive perspectives.

View Videos

(Please check whether the video is playing from the very beginning before viewing! You can click "**CC**" button to get captions.)

Video Segment 1. Administrators emphasize technology integration in the 21st-century classroom

Guiding questions: Listen carefully to the speeches given by the school principal, education administer, and university professor and think about:

(1) Why should the school implement technology integration?

(2) What roles do **teachers** and **students** play in meaningful technology integration in the classroom?

Click here to view video segment 1

Video Segment 2. A science teacher uses an instant messaging tool to teach velocity

Guiding questions: Please **Combine** the school principal's speech with the technology integration case to think about:

(3) How does using the instant messaging tool help students engage in classroom?

(4) What is the main instruction goal that the teacher wants to develop his students in this case?

Click here to view video segment 2

Video segment 3. An art teacher uses a Second Life art gallery to teach art

Guiding question: Please **combine** the teacher's speech with students' performance to think about:

(5) How does the teacher use Second Life art gallery to improve his students' learning involvement, as opposed to organizing a museum field trip?

Click here to view video segment 3.

Video segment 4. A science teacher creates a learning community on Facebook to teach electrons

Guiding question: Please **Combine** the teacher's speech and students' performance to think about:

(6) How does the teacher use Facebook to engage students in an academic way?

Click here to view video segment 4.

Video segment 5. Teachers use video modeling and online conferencing tools for professional development

Guiding question:

(7) Why do teachers need to conduct ongoing professional development, specifically in meaningful technology integration?

Click here to view video segment 5

Video segment 6. Technology integration is an adaptive approach to students' changing demands

Click here to view video segment 6

Appendix I: The Quiz for Technology Integration Knowledge and Evaluation

Research ID: ____________________ UGA email address: _______________ @uga.edu

Major: _______________________ Gender: __________________________

You are in your _______ year as of the fall semester of 2018

Part One: Professional knowledge
All of the following questions are about technology integration knowledge in the classroom. Please choose the **single most appropriate** answer to each question.

1. Meaningful technology integration in the classroom can be best described as instruction that:
A. provide students access to the internet and state-to-the-art computer and information technologies (ICTs).
B. uses ICTs to replace traditional instruction methods that use whiteboards and markers for teaching.
C. uses ICTs to convert paper-based information into digital forms and publish on the internet.
D. use ICTs to engage students in the classroom and develop the content learning.

2. Meaningful technology integration in the classroom need to comply with the following critical considerations during planning and implementing EXCEPT:
A. The teacher is using technology to develop the curriculum.
B. Students are using technology to conduct cooperative and constructive learning.
C. Technology is the focus of teaching and learning.
D. Students are engaged to produce new knowledge and perspectives.

Meaningful technology integration needs to define the appropriate roles that the teacher, students, and technology play. Thus, meaningful technology integration in the classroom …

3. defines teachers' roles as the following EXCEPT:
A. who facilitate students to get the right knowledge for developing mental models and solving problems.
B. innovative technology-using teachers who design technology-enhanced learning activities to engage student.
C. learning facilitators who can facilitate students to discern and synthesize information for meaning-making.
D. disseminators of knowledge who are actively teaching knowledge that they have developed by giving lectures and conducting formative and summative assessments.

4. defines students' roles as:
A. efficient learners who can effectively pull up the notes saved on Google drive and search on the internet to complete school assignments.
B. digital learners and users who have access to the internet and state-of-the-art technology in the school and at home.
C. critical learners who discern and synthesize information collected from a myriad of resources including the internet for meaning-making.
D. independent learners who are supported by the internet and technology to look for information to complete school assignments correctly.

5. defines the roles of technology as:
A. an information vehicle for converting learning content between the internet to authentic classrooms.
B. a teachers' intellectual partner for disseminating knowledge to students.
C. an information vehicle for regulating student interactions.
D. a platform for facilitating problem solving, learning communications and collaborations.

Part Two: Case Study

Case Background Information:
Singapore has become one of the top-scoring countries on the PISA tests. Ngee Ann Secondary School is one of the country's seven "Future Schools," public schools which emphasize the use of technology, digital media, and the integration of 21st century skills. What follows are three technology integration cases conducted in Ngee Ann Secondary School.

In the following tasks, we will evaluate the three technology integration cases.
Case 1. A science teacher uses an instant messaging tool to teach velocity

A male science teacher is teaching velocity in a class. After he has given a lecture on the concept of velocity, he uses an instant messaging tool in the classroom to conduct ask-and-answer learning activities. He proposes a question and asks students to use their cell phones to tweet answers to a designated social media website. He also uses the same method to ask students to tweet their questions in the classroom.

6. What is the most significant role that students play in Case 1?
A. **Efficient learners** who use their notes taken during the lecture to think about the answer.
B. **Digital learners and users** who have access to the internet and are allowed to use their cell phones for the learning purpose in the classroom.
C. **Critical learners** who are actively participating in learning and thinking.
D. **Independent and efficient learners** who are supported by the internet and technology to look for information to answer questions correctly.

Case 2. An art teacher uses a Second Life art gallery to teach art

A male art teacher uses Second Life as a platform to teach art. The school has set up several art galleries on Second Life that have collected artworks created by local artists. He selects a gallery based on the curriculum and organizes students to visit the gallery. He assigns two students at each terminal of the gallery to explore together. Students discuss about artworks using elements and principles of design and read other students' comments, and they can leave notes at the gallery.

7. What is the most significant role that Second Life platform plays in Case 2?
A. **An information vehicle** that transports the local artists' artworks from the physical museum to the virtual gallery to provide convenience for teachers and students visit and exploration.
B. **The teachers' intellectual partner** who helps the teacher organize diversified learning activities to stimulate students' learning interest.
C. **An information vehicle** that can record and regulate students' activities during their exploring the art gallery within the scope of the curriculum.
D. **A social media** that supports the teacher to develop an engaging learning experience and facilitates students to use knowledge and develop 21st Century skills.

8. Why is it appropriate to use Second Life in Case 2?
A. Students can develop creativity because their creative ability will be inspired by the local artists' artworks that are specially selected by the school.
B. It demonstrates to students the most up-to-date technology developed at that time (when the video was produced).
C. It is adaptive to the art class because the local museum exhibition schedule is always adjusted so that it is difficult for school teachers to make their schedules to meet the schedule of the local museum.
D. It is adaptive to the classroom instruction because the teacher can engage students' participation in deep learning and students can conduct online discussions and communications.

Case 3. A science teacher creates a learning community on Facebook to teach electrons

A female science teacher creates a learning community on Facebook when teaching the concept of the electron. In the online community, students discuss their learning by asking and answering questions about the topic.

9. Which statement best supports the selection of Facebook as a good consideration for Case 3?
A. Facebook is such a popular and engaging social media and almost every student loves using it (when the video was produced), so it can make the teacher more connected with students.
B. Facebook provides the teacher convenience to conduct technology integration in the classroom because every student is good at using it and the teacher does not need to spend extra time to teach them to use it.
C. Facebook helps the teacher improve classroom management by reducing students’ distractions and develop the curriculum by facilitating students’ collaboration in problem solving.
D. The teacher is doing a study that investigates ways to turn a social medium from a consumer-oriented, learning-distraction technology into a knowledge-production, learning-engagement technology. Facebook is a good choice for the study because it is very popular and well-developed.

10. What are your perceptions about technology integration?
A. Allowing students to bring their technology devices into the classroom is not beneficial for classroom instruction as not every student is self-disciplined and very few teachers can handle the issue well. Using traditional methods in the classroom instruction can prevent the issue from occurrence.
B. Teachers can engage students by using traditional tools and without using technology. Using technology to engage students' participation in learning and motivate students' interest is just an excuse for those teachers who do not make a good preparation for teaching.
C. Integrating technology into classroom is very meaningfully as the teacher can leverage the use of technology to make a significant impact on classroom instruction.
D. Technology integration is not a necessary skill for teachers because it brings teachers extra work apart as they have to learn new technology and figure out a sound plan for leveraging the use of technology in the classroom.

Appendix J: Cognitive Load Survey

Research ID: ______________________ UGA email address: _______________ @uga.edu

Instructions:

Please rate how much you agree with the following statements that describe your perceived mental work while viewing the video(s) using one of the following video's instructions designated by your instructor: (1) viewing a whole video, (2) viewing video segments, (3) viewing a whole video with guiding questions provided, or (4) viewing video segments with guiding questions provided.

Definition of Scale:

In the scales 1-10, the higher the number the surer you are, while the lower the number the less sure you are. For example, 0 means Strongly Disagree, while 10 means Strongly Agree. Please be honest in marking you really feel sure.

1. The topics covered in the video(s) were very complex.
2. The video(s) covered content that I perceived as very complex.
3. The video(s) covered very complex concepts and teaching practices regarding technology integration.
4. The video instruction method(s) (e.g., viewing a whole video, or viewing segmented videos, or providing guiding questions) were, in terms of learning, very ineffective.
5. The video instruction method(s) (e.g., viewing a whole video, or viewing segmented videos, or providing guiding questions) were distracting.
6. The video instruction method(s) (e.g., viewing a whole video, or viewing segmented

videos, or providing guiding questions) really enhanced my understanding of the topics covered in the video.

7. The video instruction method(s) (e.g., viewing a whole video, or viewing segmented videos, or providing guiding questions) really enhanced my knowledge and understanding regarding technology integration.
8. The video instruction method(s) (e.g., viewing a whole video, or viewing segmented videos, or providing guiding questions) really enhanced my understanding of content covered in the video.
9. The video instruction method(s) (e.g., viewing a whole video, or viewing segmented videos, or providing guiding questions) really enhanced my understanding of concepts and teaching practices regarding technology integration.

Open-ended questions

(For the control condition)

10. What are your perspectives of the video used in the study?
11. What are your perspectives of viewing the whole video from the beginning to the end, as opposed to viewing segmented videos?
12. Would you like to have several guiding questions for viewing the video? Why or why not?

(For the segmentation condition)

10. What are your perspectives of the video used in the study?
11. What are your perspectives of viewing segmented videos, as opposed to viewing the whole video from the beginning to the end?
12. Would you like to have several guiding questions for viewing the video? Why or why not?

(For the self-explanation condition)

10. What are your perspectives of the video used in the study?
11. What are your perspectives of viewing the whole video from the beginning to the end, as opposed to viewing segmented videos?
12. What are your perspectives of having guiding questions in the instruction, as opposed to without provision of guiding question?
13. Do you think that the amount of guiding questions is so many that brings your extra mental work? Why or why not?

(**For the combination condition)**

10. What are your perspectives of the video used in the study?
11. What are your perspectives of viewing segmented videos, as opposed to viewing the whole video from the beginning to the end?
12. What are your perspectives of having guiding questions, as opposed to without provision of guiding questions?
13. What are your perspectives of the amount of guiding questions used in the instruction?