Instructional Mathematics Videos and the Flipped Classroom

A Thesis

Submitted to the Faculty of Education

in Partial Fulfillment of the Requirements

for the Degree of

Master of Education

University of Prince Edward Island

Melissa D. MacLean

Charlottetown, PE

March 2016

ABSTRACT

With the increased use of the flipped classroom model and growth of the online learning industry, the use of instructional videos has become a popular way to learn outside the classroom. The purpose of this study was twofold. First, to investigate video design formats and video characteristics that could positively influence student engagement. Second, to gain insight into teacher experiences creating instructional videos. Open- and close-ended survey items were collected in three phases to solicit participant responses. Findings revealed that the quality of different instructional videos produced a statistically significant difference in self-reported levels of engagement, which was attributed to the pedagogical accuracy and clarity in the videos. Based on findings from this study, a video design framework was proposed that included characteristics such as, opportunities for students to practice, and closing the video with a summary recap and others. When examining issues associated with designing instructional videos, teachers reported that video creation was a time-consuming and challenging task. However, teachers' responses also indicated that instructional videos are a valuable resource, and creating an instructional video provided them with the opportunity to collaborate and reflect on pedagogy. This study concludes with recommendations to the Technological Pedagogical Content Knowledge framework applied in this study and provides guidelines for instructional video development.

Key Words: Instructional videos, flipped classroom model, video characteristics, student engagement, mathematics education, pedagogy

ACKNOWLEDGEMENTS

I would, first and foremost, like to thank my thesis supervisor, Dr. Tess Miller, at the Faculty of Education, University of Prince Edward Island. Dr. Miller's expertise and continued support allowed me to grow professionally and produce a thesis of which I am proud. There is no doubt in my mind that Dr. Miller drove me to achieve my maximum potential, of which I am very appreciative. Her support and guidance was invaluable. Again, given that Dr. Miller has been my supervisor for a number of years, I cannot express how much I appreciate her patience and the time that she has devoted to my research.

Besides my supervisor, I would like to thank Dr. Susan Dawson my committee member as well as Dr. Jane Preston and Dr. Martha Koch who served on the examining committee. Their encouragement, insightful comments, and discussions regarding my research were immensely helpful.

In addition, I would like to thank the Faculty of Education at the University of Prince Edward Island for accommodating my needs as I pursued my degree from a distance while I was living and working in China. When I began my master's degree, there was no official distance program yet Cathy Hennessey helped me build a program that allowed me to succeed.

Finally, I would like to thank my friends and family for their continued support, especially Riki Sulis and Jeremy Dwan who spent many hours reading my paper and discussing my research. Thank you!

Table of Contents

List of Tables

List of Figures

List of Abbreviations

App – Application available on electronic devices

ANOVA – Analysis of Variance

ATMI – Attitude Towards Mathematics Inventory

BEd – Bachelor of Education

ESL – English as a Second Language

HERI – Higher Education Research Institute

MEd – Masters of Education

MSLQ – Motivated Strategies for Learning Questionnaire

OECD – Organization for Economic Co-operation and Development

PCK – Pedagogical Content Knowledge

PhET - Physics Education Technology

PPT – Microsoft PowerPoint

SEMS – Student Engagement with Mathematics Survey

SPSS – Statistical Package for the Social Sciences

STEM – Science, Technology, Engineering, and Mathematics

TCK – Technological Content Knowledge

TPACK – Technological Pedagogical Content Knowledge

TPK – Technological Pedagogical Knowledge

CHAPTER ONE

There has been a drive to incorporate technological advancements in the classroom to improve the quality of education (Groff, 2013; Organisation Economic Cooperation Development [OECD], 2010; Osborne, 2014; Papert & Markowsky, 2013). It is necessary to facilitate educational growth in this area, because students are constantly surrounded by digital devices (Fullan, 2013; Groff, 2013; Papert & Markowsky, 2013) and must acquire technological literacy to be a productive member of society (OECD, 2010, 2013). Technology has been an asset in the classroom because technological tools such as word processors with spellcheck features, voice-to-text translators, writing templates, digital audio books, 3D geometric software, graphing software, and mathematical apps helps to address the diverse needs of students (Groff, 2013; Papert & Markowsky, 2013). Due to this wave of technological advancements in the classroom, pedagogy has also shifted to include a more interactive approach where, in addition to collaborate learning, students learn through using information technologies as well (Collins & Halverson, 2010; Hechter & Guy, 2010; *"What is TPACK?",* n.d). Instructional videos are one form of information technology that have become a popular way to learn outside of the classroom (Burget, Pedaste, Uger, & Lõhmus, 2014; Guo, Kim, & Rubin, 2014; Lloyd & Robertson, 2012; Snyder, 2013). For example, instructional videos have become a critical component in 98% of all online learning organizations (Roth, 2016). The online learning industry is valued at USD 107 billion in 2015, which is a testament to the growing popularity of this learning technology (McCue, 2014). Other evidence of this growing educational sector is the Lynda.com online learning site that utilizes instructional videos, a website was purchased for USD1.5

billion in 2016 (Nemo, 2016). The growth of this industry signifies an educational trend towards digital online learning, which is founded on instructional videos as the primary method of knowledge mobilization. Instructional videos are not only being used and developed by educational companies and large business organizations but also by teachers who have been using instructional videos as homework assignments. Students view a video before coming to class thus leaving classtime to collaborate with peers and the instructor about the learning. Watching a video as a homework exercise instead of traditional questions or assignments has been dubbed the flipped classroom (Love, Hodge, Gradgenett, & Swift, 2014).

The infiltration of technological advancements into society and its subsequent incorporation into classrooms prompted educators to experiment with the flipped classroom model of instruction (Bishop & Verleger, 2013; Chen, Wang, Kinshuk, & Chen, 2014; Groff, 2014). The flipped classroom is a specific type of blended learning that delivers instruction digitally outside the classroom (Staker & Horn, 2012), so that class time can be reserved for student-centered activities (Chen et al., 2014; Kim, Kim, Khera, & Getman, 2014; Love et al., 2014). It is important to note that instructional videos are one of two major components of the flipped classroom environment, functioning as the primary tool to deliver instructional content. The second major component is the collaborative classroom. The majority of research on the flipped classroom has focused on the collaborative or in-class activities and not the use and development of instructional videos. Thus this research fills a gap in literature that is needed to guide the future development of instructional videos.

Purpose

The purpose of this research was to investigate the quality of videos in terms of their design formats and pedagogical characteristics that influence student engagement. The second purpose was to gain insight into teachers' experience in creating instructional videos. The three research questions posed for this study were:

1. To what extent do different design formats promote student engagement?
2. To what extent do students perceive the pedagogical characteristics of: establishing context, effective explanations, minimizing the cognitive load, and engagement as helpful in their learning?
3. What are teacher challenges and reflections in creating instructional videos?

Examining student perceptions and preferences in video design format as well as other video characteristics is critical to producing effective instructional videos. Given that it is the pedagogy and not the technology that teaches students (Earle, 2002; Okojie, Olinzock, & Okojie-Boulder, 2006; Osborne, 2014; Snyder, 2013), it was hypothesized that students would perceive video characteristics and video design formats rooted in accurate and well-communicated pedagogy as beneficial to their learning. It was also hypothesized that teachers may experience challenges in learning different technologies to enhance pedagogical techniques in their videos (Stoilescu, 2015) as well as be challenged with the time commitment involved in creating videos. These hypotheses were aligned with common challenges reported in other research (e.g., Hechter & Guy, 2010; Shafer, 2010; Thomson, Bridgstock, & Willems, 2014).

Significance of the Study

Considering that integration of technology can promote educational growth, this study aimed to provide educators with strategies to guide the development and use of effective instructional videos. If the current shift in education is to integrate technology into teaching and learning (Earle, 2002; Groff, 2013; OECD, 2011; Osborne, 2014), then research is needed to explore the use and development of instructional videos as well as learn about student and teacher perceptions pertaining to instructional videos. The success of this paradigm shift depends on teacher desire and ability to integrate technology for the benefit of student learning. Given that prior research has commonly studied the flipped classroom model as a whole (Long, Logan, & Waugh, 2016), this study will fill the research gap on the video development component of the flipped classroom.

Definition of Instructional Videos

An instructional video is an audio-visual file of some aspect of the curriculum that is delivered to students digitally. Instructional videos can also be called screencasts (Lloyd & Robertson, 2012), video lectures (Bishop & Verleger, 2013), web-lectures (Day & Foley, 2006), or video podcasts (Kay, 2014). In exemplifying differences, a screencast can be a PowerPoint presentation with an audio component whereas a video lecture is a digital file of an instructor giving a lecture. The later file captures what the instructor writes on the board and what he/she says. A video podcast combines the audio component with visual media such as a mathematical app modeling the Pythagorean Theorem.

Rationale for Using Instructional Videos

The rationale for using instructional videos is to promote passive learning to happen outside the classroom and in turn, reserve the classroom for student focused learning (Long, et al., 2016). Passive learning can be accomplished through an instructional video that students can watch outside of class (Long et al., 2016). Since the lesson format is recorded digitally, students can rewind sections, press pause to think about and connect ideas, and/or review the video lesson at a later date when it is time to prepare for a test,for example, researchers reported that instructional videos were particularly useful for English-as-a Second-Language (ESL) learners (Yong, Levy, & Lape, 2015). Instructional videos allowed this group of students to review and replay the instruction, an option that is not available in the traditional environment (Yong et al., 2015). Multiple studies have reported that the flipped classroom was a highly effective learning environment across various subject contexts (Kay, 2012; Lloyd & Robertson, 2012; Love et al., 2014; Moore & Smith, 2012; Rackaway, 2012; Sahin, Cavazoglu, & Zeytuncu, 2014; Thomson et al., 2014). However, half of the appeal of the flipped classroom was the video and the other half, the opportunity to change what happens in the classroom (Mason, Schuman, & Cooke, 2013; Morgan, 2014).

Using the flipped classroom approach, teachers were able to design their instructional practices to meet the diverse needs of their students (Fulton, 2012; Herreid & Schiller, 2013). This approach allowed for the majority of class time to be dedicated to student-centered activities rather than teacher-directed activities (Chen et al., 2014; Kim et al., 2014; Love et al., 2014). For this reason, for the most part parents have been supportive of this mode of instruction (Fulton, 2012). Based on a voluntary survey of parents from a study in a low-achieving high school in Minnesota, Fulton (2012) found that 84% of parents indicated that the flipped classroom was their preferred choice of instruction. In particular, one parent argued that:

> The flipped classroom seems to be a much better use of the teacher's time. It also is less frustrating for the student when they need extra help as the teacher is available during class time, ending the necessity of going in before/after school to get needed help. (Fulton, 2012, p. 16)

With the lecture delivered through homework via instructional videos, teachers are no longer confined to the front of the class. As a result, they are able to circulate and answer questions during class time. Teachers can thus provide more engaging and interactive learning opportunities (Kim et al., 2014; Love et al., 2014). The use and development of effective instructional videos can provide teachers with the opportunity to transform the classroom drawing on technology to *humanize* the classroom, since there are more increased opportunities for students to work with their peers and one-on-one with their teacher (Khan, 2011). Compared to a traditional mathematics classroom, the flipped classroom model allows students and teachers to take a more active role both in the classroom and out of the classroom, as Table 1.1 describes.

Table 1.1

Comparison of Flipped Classroom to a Traditional Classroom

	Traditional Mathematics Classroom		Flipped Classroom	
	In- Class Component	Out-of-Class Component	Out-of-Class Component	In-Class Component
Activity	Lecture (explain, present and examples	Series of Textbook-type questions	Watch Videos	Active Learning Activities
Student Engagement	Passive Learning (listening & watching the "expert")	Apply Knowledge - procedural skills	Able to pause, rewind and review explanations	Active Learning Conceptually challenging, interact with peers
Teacher Role	Deliver information	Not present	Deliver information through screencasts	Working with small groups, or individual students

To implement a flipped classroom model of instruction, teachers select or create videos to deliver instruction. There are a number of websites that offer educational videos; however, they vary in quality. Table 1.2 lists a sample of websites that offer educational videos, such as Khan Academy, Brightstorm and Coursera. Although instructional videos are readily available, it may be difficult to find appropriate videos that are congruent to course outcomes and pedagogically accurate. For example, Sal Khan, creator of Khan Academy videos does not have a Bachelor of Education to create pedagogically accurate videos and has been criticized by teachers about his explanations of mathematical concepts (Ani, 2013). Furthermore, some studies reported that students preferred instructional videos that had *teacher-presence* indicating that teacher-made instructional videos may be preferred over videos accessed on the internet, but this finding is based on two studies with small sample sizes (Guo et al., 2014; Moore, Gillett, & Steele, 2014). Guo et al. (2014) and Moore et al. (2014) also recommended that teachers develop their own instructional videos; however, they did not take into account the time commitment to make the videos, which was found to be a negative factor in other studies (Corbally, 2005; Hechter & Guy, 2010; Thomson et al., 2014). Lastly, if teachers are to create instructional videos, they must have the technological expertise, which places an additional strain on teachers who already feel overworked (Kaleli-Yilmaz, 2015; Stoilescu, 2015; Thomson et al., 2014).

Table 1.2

Educational Video Websites

Name	Website
Khan Academy	khanacademy.org
Brightstorm	brightstorm.com
CosmoLearning	cosmolearning.com
Coursera	coursera.com
edX	edx.org
WatchKnowLearn	watchknowlearn.org
MathTV	mathtv.com
TeacherTube	teachertube.com
TED	ted.org
Udemy	udemy.com
YouTube	youtube.com/edu

Theoretical Framework

Given that the purpose of this study was to explore the quality and development of instructional videos in mathematics classes, the Technological Pedagogical Content Knowledge (TPACK)[1] framework was utilized to explore the implications of instructional videos as a form of technology integration in an educational context (Mishra & Koehler, 2006). Integrating technology to enhance learning requires teachers to draw on knowledge related to the subject content (e.g., mathematics), pedagogy, and technology (Mishra & Koehler, 2006). These three domains describe teachers experiences with technology integration in four ways: (a) pedagogical, content, and knowledge (PCK), (b) technological, content, and knowledge (TCK), (c) technological, pedagogical, and knowledge (TPK), and (d) technological, pedagogical, and content knowledge (TPACK) (Mishra & Koehler, 2006). Figure 1.1 illustrates the three domains of teacher knowledge and the four ways in which technology is integrated thus modeling the complex nature of teacher knowledge that is required to integrate technology successfully (Mishra & Koehler, 2006).

[1] The A in TPACK does not represent anything.

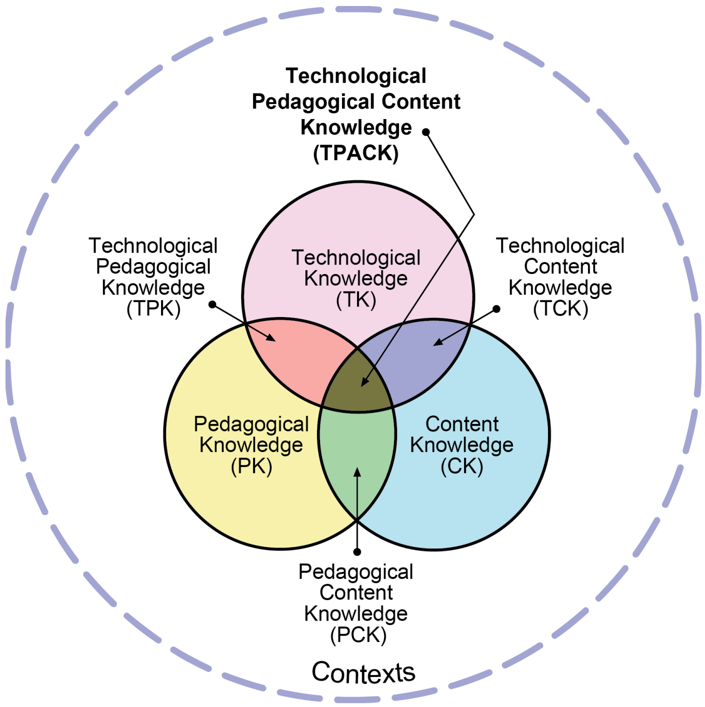

Figure 1.1. Technological Pedagogical Content Knowledge (TPACK). Reproduced with permission of the publisher, © 2012 by tpack.org

The TPACK framework suggests that technology is integrated successfully when teaching draws from all components in this framework. The following sections describe the three components of TPACK and how they were utilized to explore the use and development of instructional videos.

Pedagogical Content Knowledge (PCK)

PCK considers teachers' knowledge of pedagogical practices related to teaching content (Mishra & Koehler, 2006). A framework of pedagogical characteristics for effective mathematics videos was developed by Kay (2014) who suggested that effective elements of a mathematics instructional video consisted of four key components: establishing context, creating effective explanations, minimizing cognitive load, and engagement, which is presented in Table 1.3. To establish the context, Kay argued that problems should be clearly labelled and the narrator should provide background information and explain key elements of the problem *before* beginning to solve the problem (Kay, 2014). Effective explanations emphasized that the problems be broken up into meaningful steps and the reason for using each step is clearly articulated. Kay (2014) also explained that visuals, such as diagrams, pictures, or tables, could be used to help organize the problem. To minimize the cognitive load, the video include easy-to-read handwriting and a clear layout. Also, to minimize the cognitive load, key information should be written down, but not all at once, and highlighted so that key areas of the problem are visually emphasized. Finally promote engagement, the length of the clip should be approximately 5 minutes and avoid any distraction behaviours or habits that may distract the learner. Also, including a student practice problem can promote engagement (Kay, 2014). Kay (2014) used direct evidence from a survey and student comments to conclude that pedagogical characteristics such as problem selection, step-by-step explanations, use of visual supports, and providing a corresponding student problem to work through, were effective. Videos created for this study were developed according to this framework.

Table 1.3

Key Components for Developing Video Podcasts

Establishing the Context

Problem Type: An appropriate problem is chosen for the concept being presented (e.g., focuses student on specific concept, numbers are select carefully).

Clear Problem Label: The problem is clearly labelled and displayed at the beginning of the clip.

Background Information: The context and type of problem is clearly articulated at the beginning of the clip.

Explain Key Elements: Key elements are clearly articulated *before* trying to solve it. Don't simply read the problem, rather, highlight key features that learners should attend to.

Effective Explanations

Meaningful Steps: Problem is broken down into meaningful chunks.

Explain all steps: The reason for conducting each step is explained (so students can understand why a procedure/step is being used).

Use of Visuals: Diagrams/pictures/tables used in the clips helped organize/clarify/illustrate key aspects of the problem.

Minimizing the Cognitive Load

Readability: The writing in the clips is easy to read.

Write down key information: The important elements (terms/ definitions/ formulas/ procedures) are *written down as needed* (not all at once).

Layout: The layout of the clips is easy to follow (e.g., well organized, not crowded, even horizontal lines).

Highlighting: Key areas of problems are visually emphasized (e.g., different colour, highlighting, circled).

Engagement

Engaging Voice: The tone of the voice is engaging (e.g., was not flat or monotone).

Pace: The pace of the clip is good for learning.

Length of Clip: The clip is an appropriate length (5 minutes is about right).

Distractions: There were no behaviours/habits that would distract a student.

Student Problem: Student worked on their own problem while listening to the explanation of a teacher problem.

Note. Adapted from Kay (2014).

Technological Pedagogical Knowledge (TPK)

According to the TPACK framework for integrating technology, one of the components for success is the application of pedagogical techniques that are optimized by technology (Mishra & Koehler, 2006). In terms of mathematics pedagogy, technology can be utilized to make mathematics visual and dynamic (Stoilescu, 2015). For example, Number Pieces, an iPad application allows students or teachers to virtually manipulate base-10 pieces. The program shows how even parts of one area can be manipulated to form a different shape. Figure 1.2. illustrates how the iPad application could be used to model multiplication and annotate the reasoning.

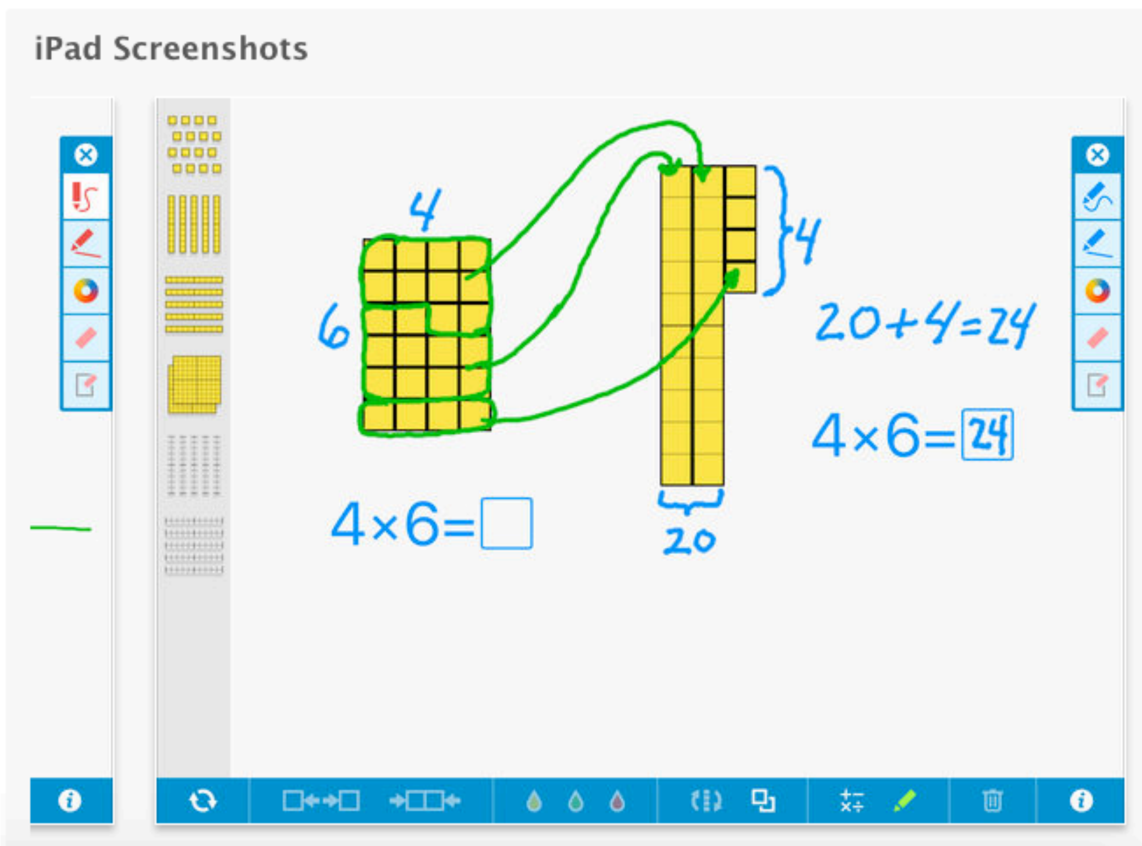

Figure 1.2. Screenshot of an app called Number Pieces modeling the use of technology in teaching pedagogical concepts.

Identifying technological pedagogical knowledge is critical for educators to develop effective instructional videos and integrate technology successfully, yet there is little research related to TPK in instructional video development. This study aims to contribute to TPK in instructional video development by drawing from cognitive load theory.

The premise of cognitive load theory is that learning requires the use of working memory, which has a limited capacity (Brame, 2015; Sweller, 1994; Sweller, 1988). Cognitive load theory considers the limited working memory and suggests that information be presented in a way that reduces the cognitive load of a learning experience. To determine the cognitive load of a learning experience, two components are considered: intrinsic load and extraneous load (Sweller, 2010). Intrinsic load is inherent to the content and the degree to which individual elements are processed simultaneously and cannot be modified, because it is related to the intellectual complexity of the subject matter (Wong, Ip, Lopes & Rajaoplan, 2012). For example, recalling the formula for area of a circle ($A=\pi r^2$) would be considered low intrinsic load, since there is little to no interaction between the elements (i.e., area and radius) (Chinnappan & Chandler, 2010). Applying the formula for the area of a circle ($A=\pi r^2$) to solve a mathematics problem would be considered a moderate intrinsic load because it requires the learner to compare elements (i.e. area and radius) and apply mathematical operations to solve the problem (Chinnappan & Chandler, 2010). An example of a high intrinsic load would be adding fractions with different denominators, because it is a complex multi-step process that involves comparing and manipulating denominators. In general, mathematics has a high cognitive load since it requires the learner to compare and relate many elements to solve problems (Chinnappan & Chandler, 2010).

Extraneous load is the cognitive effort that does not aid the learner in acquiring the learning outcome (Brame, 2015; Wong et al., 2012). High extraneous load is often characterized by lack of clear instructions or confusing information that distracts the learner (Brame, 2015). Cognitive load theory recognized that learners select information from audio and visual channels to be temporarily stored and processed in working memory (Brame, 2015). The learner must be selective in choosing what information to pay attention to since the capacity of working memory is limited (Brame, 2015). Extraneous load can be manipulated by the manner in which information is presented through audio (i.e., verbal explanations) and visual channels (i.e., written text and visuals). Applying pedagogical practices that reduce the extraneous load allows for more working memory to be allotted for the inherent difficulty of the subject (Sweller, 2010).

Considering cognitive load theory, the design of an instructional video should aim to minimize the extraneous load. To do so, four technological pedagogical practices have been identified to optimize the experience for the learner: (a) signalling, (b) segmenting, (c) weeding, and (d) matching modality (Brame, 2015). Signalling is also known as cueing and can include spotlighting important information by using a highlighter or laser to draw attention to key information. Signalling also refers to the appearance of two or three key words (Ibrahim, Antonenko, Greenwood, & Wheeler, 2012; Mayer & Johnson, 2008). Signalling or cueing helps the learner in selecting which information is important for processing in the working memory (Brame, 2015; Moreno, 2007). Segmenting presents the learner with new information in small pieces, a process that gives the learner control over the flow of new information (Brame, 2015; Moreno, 2007). Creating shorter videos and prompting students to pause in a video and try a question can accomplish this goal as well as promote student engagement (Guo et al., 2014).

Weeding is the elimination of information that does not contribute to the learning goal, such as music, background graphics, and animations, because the learner has to judge if the information is important or not, a process which can be distracting (Brame, 2015; Ibrahim et al., 2012). The fourth technological pedagogical practice involves using both audio and visual channels to present new information. This practice is called matching modality (Thomson et al., 2014). A poor example of matching modality would be a video that animates a drawing (i.e., the visual) while providing an audio explanation of an upcoming task. This matching of modality is poor, because the audio component is not narrating the drawing; rather, it is talking about what is to come next thereby overloading the visual channel (Brame, 2015). A better example of matching modality would be a video that draws a diagram while providing a verbal narration of the diagram, so that new information can be processed and complimented by both audio and visual channels (Brame, 2015). These technological pedagogical practices can aid students in storing the important details from the lesson so that they have the knowledge to apply to the in-class activity. These practices were applied to the nine instructional videos created in this thesis.

Technological Content Knowledge (TCK)

TCK is the application of technology to represent the content (Stoilescu, 2015). For example, an array diagram can be animated using PowerPoint (PPT) to demonstrate multiplication. Instructional videos can utilize many forms of technology such as presentation software, mathematical software, calculator emulators, and simulation applications all of which can represent content. In this thesis, a number of different technologies were used to communicate the content including: PPT, fraction simulator, and Pythagorean app.

Summary

To describe how teachers integrate technology the TPACK framework considers pedagogy, content, and technology as well as the complex interplay between them. TPACK recognized that teachers must have acquired the necessary knowledge before they can integrate technology successfully. The knowledge Mishra and Koehler (2006) identified were: pedagogical-content knowledge, technological-content knowledge, technological-pedagogical knowledge and technological-pedagogical-content knowledge. The TPACK framework was utilized to address the three proposed research questions. Several video design formats utilizing different forms of technology were applied to create nine instructional videos, of varying quality, for this study. Findings from this study would inform TCK and aid teachers in selecting technology to develop instructional videos. Lastly, a measure of student perceptions helped to identify effective pedagogical-content and technological-pedagogical characteristics of instructional videos. The related findings informed knowledge of PCK and TPK related to instructional videos.

CHAPTER TWO

Literature Review

A review of literature about instructional videos and their use in the flipped classroom (also known as inverted classroom) was conducted to inform the design of this study and methodology. Drawing from prior research, there was no ideal flipped classroom model (Moore, et al., 2014). Each study varied in some form, especially in terms of how the in-class component was implemented. Kay (2014), in particular, noted that there was limited research on identifying specific characteristics of an effective instructional video. In extracting the sparse literature available on this topic, the following sections synthesize the research on videos used in the flipped classroom model and students' perceptions of instructional videos. After reading and comparing multiple studies, a number of themes, insights and gaps in the research emerged. The three key areas are students' perceptions of effective instructional videos, video design formats, and pedagogical practices to implement instructional videos.

Student Perceptions of the Flipped Classroom Model

A number of early studies conducted before 2013, collected information about student perceptions of the flipped classroom model to assess to what extent the flipped classroom improved student learning. Without exception, all studies reviewed in this thesis measured student perceptions through surveys (Gilboy, Heinerichs & Pazzagalia, 2014; Guerrero, Beal, Lamb & Baumartel, 2015; Kennedy, Beaudrie, Ernst & St. Laurent, 2015; Kim et al., 2014; Love et al., 2014; Mason et al, 2013; Roach, 2014; Rossi, 2015; Sahin et al., 2014; Wilson, 2013; Wong et al., 2014; Yong et al., 2015) thus indicating that measuring student perceptions is universally valued and that the use of a survey is commonly practiced. Of the twelve studies that measured student perceptions of the flipped classroom, only three studies used professionally developed surveys with proven reliability coefficients. The first of these studies was the Science Technology, Engineering and Mathematics education (STEM) survey developed by Higher Education Research Institute (HERI) to measure students' attitudes towards Math (Yong, Levy, & Lape, 2015). Second, the Motivation Strategies for Learning Questionnaire (MSLQ) to track changes in motivation and learning strategies utilized (Kennedy et al., 2015; Yong, Levy, & Lape, 2015). Third, the Attitudes Towards Mathematics Inventory (ATMI) survey (Guerrero et al., 2015). The other nine studies developed their own survey items to measure student perceptions (Gilboy et al., 2014; Kim et al., 2014; Love et al., 2014; Mason et al, 2013; Roach, 2014; Rossi, 2015; Sahin et al., 2014; Wilson, 2013; Wong et al., 2014). Unfortunately, only one of those studies stated a measure for the reliability coefficient acting as an indicator that their collection of items were indeed measuring student perceptions (Gilboy et al., 2014). The following section provides a more detailed description of studies that reported using reliable instruments (Gilboy et al., 2014; Guerrero et al., 2015; Kennedy et al., 2015; Yong et al., 2015).

Guerrero, et al. (2015) conducted an experimental study that investigated the effectiveness of the flipped classroom in an undergraduate finite mathematics course and examined changes in students' attitudes towards mathematics, engagement, and achievement. The researchers conducted a quasi-experimental design that utilized pre- and post-measures of each independent variable to compare the effectiveness of the flipped classroom model with a more traditional model. One class was assigned the flipped classroom model ($n = 37$) and the other class was taught in a more traditional approach ($n = 31$). Students in the flipped classroom were assigned to watch videos for homework, and, during class time, students worked in groups to solve problems. Videos students watched for homework were screencasts of the notes given to the control group. An effort was made to also pose questions to students during the video and encourage students to pause the video while taking notes. To measure the change in student attitudes towards mathematics, the Attitude Towards Mathematics Inventory (ATMI) was administered twice, first to measure the student attitudes before the experiment and again at the end of the course to see the change in attitude. The ATMI survey consisted of 40 Likert scale items divided into four sub-categories: self-confidence, value, motivation, and enjoyment. Researchers found that student enjoyment and value of mathematics significantly increased in the flipped classroom. Although students seemed to enjoy the new mathematical learning environment, there was no significant difference in motivation or self-confidence.

Guerrero et al.'s (2015) study also measured student perceptions by administering two open-ended surveys that solicited students' experiences toward the use and effectiveness of the flipped classroom. During the mid-semester open-ended survey, participants generally responded that the videos had a positive impact on learning and reported that the flipped classroom approach was an effective way to learn mathematics. Students in the flipped classroom section enjoyed the increased time spent on hands-on learning, problem solving, and collaboration; hence, it was likely that the level of student engagement increased in the flipped classroom. The end-of-semester open-ended survey, showed that the number of students who viewed the videos positively, dropped, and the number of students who viewed the video negatively increased. Researchers noted that participants in the flipped section seemed to *work the system* by fast-forwarding the videos, copying notes from other students and disengaging during the in-class group activities as evidenced from two different research assistants' observations made during interviews with the instructor The instructor began to question the appropriateness of the flipped classroom model as an every-day approach. Instead of questioning the suitability of the flipped classroom model, it may have been more prudent to question the quality of what the researcher describes as a video lecture or the level of engagement during the in-class segment of the flipped classroom.

Another study also concluded: "An inverted pedagogical approach is not always best" (Kennedy, et al., 2015, p. 900). In this study, Kennedy et al. (2015) examined the effects of the flipped classroom on student performance in a university second semester calculus course and its effect on student motivation and learning strategies. These researchers differed from others in two major ways: they had a sample size larger than most studies (n = 173), and they measured motivation and learning strategies with the Motivated Strategies for Learning Questionnaire (MSLQ) survey and student achievement. The survey was divided into two sections. The first section, called the motivation section, included 31 items examining three subscales: value, efficacy, and affective component (Stoffa, Kush, & Heo, 2011). The second part of their survey focused on learning strategies section and consisted of fifty items pertaining to student use of different cognitive and metacognitive strategies (Kennedy et al., 2015). This instrument was found to be valid and reliable with a Cronbach's alpha of 0.78 for motivation and 0.71 for learning strategies (Stoffa et al., 2011). The pre-test results from the MSLQ survey identified only one significant difference between groups in the learning strategies subscale, which favoured the experimental group ($p = 0.02$). In comparison, the post-test scores of the MSLQ survey revealed three significant differences between the experimental and control groups. Firstly, the students in the experimental group had a significantly higher mean average in overall learning strategies score ($p = 0.02$). Secondly, the experimental group maintained a significantly higher elaboration learning strategies sub-scale score ($p = 0.04$) in the post-test results. Elaboration strategies included summarizing, notetaking, and creating analogies. Together, these strategies helped students store information in long-term memory by making connections between prior knowledge and the new material. The last significant difference was a higher organization learning strategies sub-scale score ($p = 0.02$) for the experimental group (Kennedy et al., 2015). The organization strategies helped the learner to select important information and make connections in the material. Organizational strategies included clustering, outlining, and selecting the main idea of a reading passage. These strategies can improve performance, because using this strategy required the learner to be actively involved in the task. Kennedy et al. (2015) also noted that there was a significant positive change for rehearsal, which involves reciting or memorizing items from a list. These findings revealed that the flipped classroom model can expand students' use of learning strategies; however, of the variables measured, students improved learning strategies was the only positive gain experienced by the experimental section. These gains did not translate to an increase in student achievement, since there was no statistical difference between achievement in the flipped classroom and control group (Kennedy et al., 2015).

Kennedy et al. (2015) also tracked changes in motivation within each group. Unlike Guerrero et al. (2015), Kennedy et al. (2015) found a significant difference in motivation between the two groups where the motivation score of the flipped section actually decreased after being exposed to this instructional style when it was anticipated to increase. The experimental group made significant negative changes in three subscales of motivation. A noteworthy finding from this study was that self-efficacy, a subcomponent of motivation, and peer learning, a learning strategies sub-scale, significantly decreased for the experimental group ($p = 0.04$, $p < 0.0001$ respectively) (Kennedy et al., 2015). Conversely, the control group made more positive changes in motivation and learning strategies than the experimental. This result is surprising, because it suggests that the flipped classroom model negatively impacted students' self-efficacy and motivation. One possible factor that could explain this negative result is the quality of the instructional videos. Kennedy et al. (2015) developed instructional videos using a tablet application, Explain Everything, that captured virtual-ink annotations and audio to produce a video. Unfortunately, the authors did not provide much detail about what the videos included or what considerations were made in the creation of these instructional tools, hence, it is not possible to determine whether low scores were a result of a poor quality video or the flipped classroom in general. The description of the videos did not extend beyond the range of video length and that PDFs or photographs were imported to demonstrate concepts visually. The lack of specific video description suggests that the researchers did not use a theory-based framework in the development of their instructional videos. If the instructional videos were poor, it is possible that students started to disengage and become unmotivated.

Overall, student perceptions of the flipped classroom model were generally positive, yet there were three studies that reported negative experiences with the flipped classroom (Guerrero et al., 2015; Kennedy et al., 2015; Yong et al., 2015). Some findings suggested that students reported more positive math attitudes with the flipped classroom model (Guerrero et al., 2015) but also reported they lost motivation and engagement after a period of time (Kennedy et al., 2015). Since each flipped classroom model was different, it is not possible to match negative results to specific elements of the flipped classroom. There may be a factor that is common between the studies that found a decline of student engagement, and one possible factor that could influence engagement is the quality of the instructional videos used.

Perceptions of Video Effectiveness

Student perceptions on the usefulness of instructional videos in facilitating their learning were generally positive (Gilboy et al., 2014; Kay, 2014; Long et al., 2016; Love et al., 2014; Roach, 2014; Sahin et al., 2014). Researchers reported that instructional videos were particularly useful for English as a Second Language (ESL) students who were able to review and replay videos and not miss instructional concepts that may have been unnoticed in a traditional lecture environment due to the challenges associated with second language learning (Yong et al., 2015). Compared to traditional lectures, video lectures have additional features that can make them more useful. "Almost all students reported an appreciation for the ability to pause, rewind, and fast-forward through the video lectures" (Yong et al., 2015, p. 917), but some students mentioned that it was hard to keep focused while watching the videos (Yong et al., 2015). According to the studies described below, students reported that instructional videos were beneficial to their learning (Love et al., 2014; Sahin et al., 2014).

Love et al. (2014) conducted an experimental study measuring student learning and students' perceptions of the flipped classroom in an undergraduate linear algebra course. Fifty-five students participated in the study, where one section was taught in a traditional lecture-style format while the other section was taught using the flipped classroom model. Participants in the flipped classroom watched narrated PowerPoint presentations and answered a daily assessment as a pre-requisite for the next day's class. Class time was reserved for asking questions and completing math problems that the traditional class was assigned as homework, which was completed with peers and the instructor present. Love et al. (2014) found that although both sections scored similarly on the final exam, there was a significant difference in performance between the second exam and the first exam ($p < 0.034$) where students in the flipped section performed significantly better than the traditional section. Furthermore, 96% of students in the flipped classroom reported that they learned significantly more ($p < 0.001$) from the videos than from the lecture.

Love et al.'s (2014) findings were mirrored in a study by Sahin, et al. (2014), who investigated the effectiveness of the flipped classroom on mathematical achievement as well as explored students' perceptions of the flipped classroom. Sahin et al. (2014) argued that the use of technology would be a more attractive alternative course preparation activity as compared to reading the textbook. In this study, the flipped classroom model was delivered to 96 students in a college calculus course three times over a semester. After each implementation, students completed a survey examining their perceptions of how the videos helped prepare them for class. In addition, students completed a surprise quiz to measure achievement (Sahin et al., 2014). Unfortunately, there was no mention of what the in-class component of the flipped classroom lesson entailed, hence, the extent to which these researchers focused on the engagement component of the flipped classroom is unknown. Furthermore, given that the researchers did not implement a pre-test, it is not possible to determine whether gains in quiz scores were a result of an easy topic, the impact of the video component of the flipped classroom, or something else.

Despite these shortcomings, Sahin et al. (2014) reported that 85% of students believed that videos helped them perform better during class, and 81% of students felt more comfortable with the following day's material. Furthermore, a large majority (i.e., 83%) of students claimed that they preferred a course with instructional videos than without. Since an indicator of the video quality was not provided, it is unknown what influenced student preference for these instructional videos. Similarly, Sahin et al. (2014) also reported that students scored statistically higher (p = .001) on the surprise quizzes that followed the flipped lessons, compared to the traditional lessons. As previously noted, this finding raises concerns, because since there was no measure of students' abilities prior to viewing the instructional video. Although participants in Sahin et al.'s (2014) study favored the use of instructional videos in the flipped classroom, which parallels the findings of other research on student perceptions of the usefulness of the instructional videos in supporting their learning (e.g., Gilboy et al., 2014; Kay, 2014; Long et al., 2016; Love et al., 2014; Roach, 2014; Yong et al., 2015), this study contained too many design flaws to provide insight into further research, other than the need to provide an indicator of the quality of instructional videos used in flipped classrooms. Based on these studies, research on indicators or characteristics of an effective video is limited (Kay, 2014). Despite this shortfall in research, the number of instructional videos on YouTube has increased dramatically (Kay, 2014). If teachers are developing their own instructional videos or selecting videos to use for instruction, then it would be useful to have a set of characteristics to self-evaluate instructional videos to determine if they are appropriate and effective for students.

Pedagogical Characteristics of Effective Videos. Kay (2014) developed 59 instructional videos for a first-year calculus course using a theory-based framework that included 16 features that were organized under four main categories: establishing context, creating effective explanations, minimizing cognitive load, and engaging students. The purpose of his study was to develop and evaluate the theory-based framework for designing worked-example video podcasts (i.e., instructional videos). In this study, the researcher used worked-example video podcast to describe the type of video, which was described as similar to Khan Academy with a black background and virtual ink annotations (Kay, 2014). In layman terms, the instructor recorded the narration and writing using a tablet application, which modelled a black/whiteboard in the classroom. The videos used in this study were created for students in a university calculus course as a supplementary resource and, therefore, were not mandatory. Students viewed the video podcasts and following the video podcast. Students were prompted with a survey that documented their attitudes and perceptions pertaining to the usefulness of the video. In addition to the survey, students were also asked to rate their knowledge of the topic before and after viewing the video podcast. Although testing students on their knowledge would be more accurate, the researchers argued that other studies have concluded that students are accurate in assessing their knowledge (Kay, 2012).

With regard to Kay's (2014) study, about 60% (n = 488) of the students chose to watch the video podcasts for at least one of the five topics. Overall, nearly three quarters of the students who viewed the video podcasts rated them as useful (29%) or very useful (45%). Furthermore, about 80% of students agreed or strongly agreed that the video podcasts helped them understand mathematics concepts. In addition to student perceptions of the video podcasts, students were asked to self-rate their pre-calculus knowledge before and after the students viewed the video podcast. Kay used a paired *t*-test, which revealed a significant difference in learning gains for all five pre-calculus topics. The video podcasts had a moderate positive effect on students' self-assessment of their pre-calculus knowledge; effect sizes ranged from 0.30 to 0.53. Together, the positive perceptions and gains of knowledge reported by students, strongly suggest that the video podcasts created in this study were effective. Therefore, the framework developed by Kay is useful in determining pedagogical characteristics of effective video podcasts and to evaluate the effectiveness of the instructional mathematics videos created for this thesis.

It should be noted that, in this study, videos were created to prepare students for the in-class activity and not as a supplementary resource for students to review. Given the absence of guidelines governing videos purposefully created for the flipped classroom, the pedagogical characteristics of an effective instructional video are unknown. This oversight in previous research calls for more research in this area. Therefore, to address the research questions of this study, the purpose, content, and other characteristics of the instructional videos were clearly documented and compared. Also, there are a number of ways to design videos that utilize different forms of technology, and Kay (2012) only studied the characteristics of videos for one format of video. The following section describes the video design formats of instructional videos used in flipped classroom research.

Video Design Formats

Most flipped classroom research reported using some variation of audio and video infused slideshows (Day & Foley, 2006; Moore, et al., 2014; Moravec, Williams, Aguilar-Roca, & O'Dowd, 2010; Sahin et al., 2014; Wong et al., 2014). Therefore, the term *instructional video* is loosely applied in that it can refer to screencasts of PowerPoint slides and recorded audio explanations or, in general, as defined for this thesis, an audio-visual file that can be digitally accessed and is used for instruction. Researchers often noted that teacher-created videos were superior to using videos from websites (Bishop & Verleger, 2013; Fulton, 2012; Moore et al., 2014;) such as YouTube, TeacherTube, and Khan Academy, which is likely due to keeping content aligned with the course and controlling the teaching pedagogy (Fulton, 2012; Thomson et al., 2014). However, Roach (2014) assigned videos from Khan Academy, Public Broadcasting Service (PBS), Freakanomics, and other websites for his post-secondary economics class and found that 76% of students reported that these video lectures helped them learn. Of the studies considered for this literature review, Roach (2014) was the only study that used videos from the Internet. All other studies delivered teacher created video lectures (Gilboy et al., 2014; Guerrero et al., 2015; Kennedy et al., 2015; Love et al., 2014; Mason et al., 2013; Rossi, 2015; Sahin et al., 2014; Wong et al., 2014; Yong et al, 2015).

Based on the literature presented above, there are four different ways to produce an instructional video. They are screencasts, live video capture, a blend of screencasts and live video capture, and live virtual-ink annotation videos. Screencast videos are videos created using a screencasting software, such as Camtasia or Screencast-o-matic (Douch, 2014) that capture the images on a computer screen and audio record the instructor narrating the slides, which is thereafter converted to a video file. For example, teachers could *present* their PowerPoint and record themselves narrating each slide. Alternatively, the screencasting software allows the teacher to cut and edit the narration. Camtasia is an example of screencasting software and has an additional feature that allows the teacher to highlight the cursor so that the teacher can point and highlight important information or draw attention to images, an important feature that can be used to signal and reduce cognitive load. A number of studies opted for using screencasting software because of these features (Little, 2015; Love et al., 2014; Moore et al., 2014; Wong et al., 2014).

In comparison to screencasting, live video capture involves video and audio recording using an electronic device that has video recording capabilities, such as a phone, tablet, or video camera. Typically, educational videos created in this way would feature the teacher in front of a whiteboard explaining the lesson most similar to being in the classroom observing a teacher give a direct instruction lesson. Of the research examined for this review, the only study that used this method of video production was Moore et al.'s (2014) study that accessed videos from Brightstorm, an educational site that has a collection of academic videos filmed in this manner. Moore et al. (2014) decided to abandon the use of this video part way through their research due to students' request for a video that featured their own classroom teacher.

Another video design is a blend of screencasts and live video capture (Day & Foley, 2006; Thomson et al., 2014). These videos featured screencasts of slides and, in a corner of the screen, a live visual of the teacher's head explaining the lesson. This type of video design format involves installing a Microsoft plugin and a webcam to record video. This format was rarely referred to in the literature.

Lastly, live virtual-ink annotation format videos are created with tablet applications and screencasting software the records the writing and audio narration. This format is similar to screencasts, but a distinction was made since screencasts typically have prepared images and typed-text while the live virtual-ink annotation format utilizes live handwriting and the audio narration simultaneously. This video design format was also a popular choice among researchers (Kennedy et al., 2015; Mason et al., 2014; Rossi, 2015; Yong et al., 2015).

Of the research that investigated the effectiveness of the flipped classroom model (and described the video production enough to classify), eight of 10 studies chose either the screencasts of PowerPoints or screencasts with live virtual-ink annotation. Through this synthesis of literature, there is an absence of research investigating the effectiveness video design formats.

Implementation of Videos in the Flipped Classroom Model (TPK)

Another avenue of research examined how instructional videos were implemented in the flipped classroom. The flipped classroom requires students to learn outside of the classroom, therefore, pedagogical practices were considered to ensure that students were engaged while watching the videos. The two pedagogical practices noted in literature focused on video scaffolds and assessment of content learned after watching instructional videos.

Video Scaffolds. In the flipped classroom, the instructional video is intended to prepare students for the following days' active learning activities. Therefore, it is crucial that students watch the videos and come to class with knowledge and understanding of the video content. Since the instructional video is assigned as homework, certain structures need to be in place to ensure that students are coming to class prepared for the active learning activities. Raths (2013) developed a list of advice for teachers intending to implement instructional videos in the flipped classroom. Raths (2013) argued that it was important to dedicate time to explain the pedagogy of videos to generate student buy-in as well as teach students and parents how to watch the videos. He further added that when introducing students to the flipped instructional method, they must be taught how to learn independently when watching a video. To enhance student engagement in the video, teachers can provide scaffolding, such as fill-in-the-blank notes, to help students highlight the important information as they watch the video (Brame, 2015). Other studies provided worksheets containing questions to answer while watching the video or provided fill-in-the blanks notes of the big ideas (Gilboy et. al, 2015; Guerrero et al., 2015; Little, 2015; Moore et al., 2014; Roach, 2014). Moore et al (2014) argued that scaffolds helped students focus on the big idea, as well as, functioned as an assessment tool to gauge their understanding. These researchers concluded by noting the need to experiment with other design variables, "such as content and structure of the supporting worksheets and whether posing questions for students to ponder and tinker with – rather than presenting worked out examples – makes a difference" (Moore, Gillett, & Steele, 2014, p. 424). Scaffolds may lessen the extraneous load on the student because the scaffold highlights the important information for students, removing some of the extraneous load put on the student. If the video does not clearly indicate when students should copy or when students should pause, the scaffold may actually create more extraneous load on the student.

Assessment of Content Learned via Video. Other strategies for ensuring students were engaged in viewing the videos focused on the use of assessments. Four studies assigned students to complete a quiz, either online before class, or had a daily quiz at the beginning of class to assess the understanding of the videos (Kim et. al, 2014; Sahin et. al, 2014; Wilson, 2013; Wong et. al, 2014). Although formative quizzes can provide valuable information to both the student and the instructor, one could speculate that using a quiz to summatively assess understanding in this manner may seem punitive to some students and thereby minimize the positive impact of the video.

Moore, Gillett, and Steele (2014) narrowed the purpose of formative quizzes as three-fold a) provides a measure of accountability to ensure that students are watching the videos b) provides information to guide instruction, and c) connects the video assignment to the classroom and provides a strong foundation for the in-class exploration. Without an assessment component, it may be very difficult for students to buy into the idea of watching a video if it is not *counted* for marks. Although formative assessment is not included in a summative mark, by assigning a quiz, the teacher is placing special emphasis on the importance of the video and connecting the video to the in-class component of the course.

Summary

Overall, students perceived the flipped classroom as a positive influence in their learning (Bishop & Verleger, 2013). Some studies reported that after learning in the flipped classroom model over a period of time, student motivation and engagement decreased (Guerrero et al., 2015; Kennedy et al., 2015). It is unclear what aspect of the flipped classroom model influenced students negatively, but one possibility could be a result of poor quality videos. Other studies have demonstrated that instructional videos are useful and effective tools to aid students in their learning (Kay, 2012; Lloyd & Robertson, 2012; Moore & Smith, 2012; Rackaway, 2012; Thomson et al., 2014); however, there is little known about the pedagogical characteristics of videos that promoted engagement and benefited learning.

There was little discussion in the literature that described which aspects of the instructional videos were effective for learners or what types of work, notes, reflections or additional questions, for example, should supplement the videos. Most literature reported that students considered instructional videos as a helpful tool to benefit learning (Gilboy et al., 2014; Sahin, 2014;). In the studies reviewed, there was an insufficient amount of detail of what was included in the videos (Guerrero et al., 2015; Kennedy et al., 2015; Little, 2015; Love, 2014; Mason et al., 2013; Moore et al., 2014; Roach, 2014; Rossi, 2015; Wong et al., 2014; Yong et al., 2015). Most articles did not describe the content on the videos, or if the videos incorporated pictures, animations, practice questions, scaffold explanations, or reviewed previous material. Therefore, it is important that future studies clearly document the content and purpose of the videos. Better, it would be ideal if future studies could provide a link to the video; however, this point may not be feasible if the videos are posted on closed student networks. Regardless, some kind of framework for ensuring the effectiveness of videos must be applied in future studies to ensure that students are receiving effective instruction. Similar to the complexity of classroom instruction, instructional videos must also be created with sound pedagogy to ensure that students are learning effectively. Strayer (2012) and Kim, Kim, Khera, and Getman (2014) agreed that future studies should more deeply investigate the use of technology in the flipped classroom model. To address this gap in literature, this thesis will investigate characteristics of instructional videos, video design formats that utilize various technologies, as well as, teachers' experiences in developing instructional videos.

CHAPTER THREE

Research Methodology

The purpose of this research was to identify video design formats and video characteristics that promote student engagement. Past studies have compared the effectiveness of the entire flipped classroom model with the traditional teaching approach (Day & Foley, 2006; Desantis, 2015; Gilboy et al., 2014; Guerrero et al., 2015; Kennedy et al., 2015; Love et al., 2014; Mason, 2013; Roach, 2014; Sahin et al., 2014; Strayer, 2012; Wong et al., 2014; Yong et al., 2015); however, research has been insufficient in determining effective methods of using instructional videos and in identifying video characteristics that students deemed valuable. Moreover, the absence of teacher perceptions on creating instructional videos for the flipped classroom model compounds the void of knowledge in this area. As such, this study aimed to fill this gap by identifying effective formats and characteristics of instructional videos and their effect on student engagement in mathematics. To further understand and identify characteristics that influence the effectiveness of an instructional video, student perceptions of each video and teachers' experiences creating instructional videos were measured. An embedded mixed methods research design was applied so both qualitative and quantitative data could be collected to respond to these areas of inquiry. This chapter highlights the methodology, research design, research questions, participants, instrumentation, procedures, and data analysis utilized in this study.

Research Design

This study employed a mixed methods approach to investigate the effectiveness of instructional mathematics videos through both quantitative and qualitative data collection (Creswell, 2012). The rationale for choosing a mixed methods design was to provide the researcher with greater scope and understanding of the research questions posed in this study (Johnson & Onwuegbuzie, 2004; Almalki, 2016). A mixed method approach provides the researcher with the opportunity to compensate for the inherent weaknesses that are apparent in a purely quantitative or qualitative approach (Almalki, 2016). Quantitative methods test a hypothesis to produce a conclusion that empirically describes the relationship among the tested variables, however, qualitative methods recognize the difficulty to accurately measure social construct variables (e.g., learning) and the importance of an insider's perspective to fully understand such complex situations (Almalki, 2016). Therefore, to gain a broader perspective and insight into the development of instructional videos in a mathematics flipped classroom, both qualitative and quantitative data was collected.

This study employed three surveys to solicit students' engagement and perceptions with the instructional videos and teachers' perceptions on designing instructional videos. The dependent variables in this study measured self-reported levels of engagement while viewing the instructional videos and students' perceptions of effectiveness of the different instructional videos. An explanatory design analysis was selected so that the qualitative responses could be used to explain the findings of the quantitative data collected during Phase I (Creswell, 2012). Table 3.1 summarizes the survey instruments used to collect the dependent variables and the corresponding research question.

Table 3.1

Variables measured and instruments used in each phase

		Dependent Variables		
	Instruments	Student Engagement in Mathematics	Student Perceptions	Teacher's Perception
Phase I	Engagement Surveys	RQ#1 – To what extent does the quality of the video promote student engagement?		
Phase II	Overall Feedback Survey		RQ#2 – Which video characteristics do students perceive as beneficial to learning?	
Phase III	Reflection Survey			RQ#3 – What are teachers' experiences in creating instructional videos?

During the first phase of data collection, quantitative data was collected in the form of a survey to measure student engagement. The survey also contained open response items to allow participants to provide insight into sources of engagement or disengagement. This information was referred to when the items for the second questionnaire were created. The second phase of data collection involved a second questionnaire designed to interpret and confirm findings from the first round of data collection. This survey also contained both qualitative and quantitative items. Lastly, to gain an alternative perception of instructional videos, teachers enrolled in a graduate course that focused on mathematics education and involved creating an instructional video to demonstrate their pedagogical understanding were asked to comment on their experiences with creating instructional videos in open response items. In sum, to investigate each of the proposed research questions, quantitative and qualitative items were included.

Research Questions and Hypotheses

The three research questions posed in this thesis were:

Research Question#1: To what extent does the quality of the instructional video promote student engagement? Quality was measured using Kay's (2014) 20 point rating system.

Research Question#2: To what extent do students perceive the four pedagogical characteristics (i.e., establishing context, effective explanations, minimizing the cognitive load, and engagement) helpful in their learning?

Research Question #3: What are teachers' challenges and perceptions towards creating instructional videos in a mathematics education context?

Examining student perceptions and preferences in video design format as well as other video characteristics is critical to producing an effective instructional video. Given that it is the pedagogy, not the technology that teaches students (Earle, 2002; Okojie et al., 2006; Osborne, 2014; Snyder, 2013), it was hypothesized that students would perceive video characteristics and video design formats that are rooted in accurate and well communicated pedagogy would be beneficial to their learning. Also, it was hypothesized that teachers may experience challenges in learning different technologies to enhance pedagogical techniques in their videos (Stoilescu, 2015), as well as be challenged with the time commitment involved in creating videos (Corbally, 2005).

Participants

Phase I and II. Participants in this study included first-year Bachelor of Education (BEd) students who were enrolled in Mathematics for Teachers, a course required by BEd students who do not have a mathematics credit in their undergraduate degree. The course was offered at the University of Prince Edward Island, Faculty of Education. The course goal was twofold: ensure that students have a solid foundational understanding of mathematics and model best teaching practices. The researcher's role in this course was to create instructional mathematics videos that aligned with the instructor's curriculum. Twelve students were enrolled in the course, six females and six males, and the course was offered twice a week, three hours each lesson, over a five-week period starting in May 2016 for a total of 30 hours of instruction. All teachers enrolled in the course voluntarily participated in this study.

Phase III. Twelve participants, four males and seven females, were recruited from a Master of Education program that focused on mathematics education. As part of a course requirement, each student created an instructional video to demonstrate his/her understanding of mathematics pedagogy. Although this group of participants were graduate students, for the purpose of clarity, they will be referred to as teachers since all participants from this group were practicing teachers. All teachers enrolled in the course participated in this study.

Creation of Instructional Videos for Phase I

Instructional mathematics videos were created using different video design formats or platforms in phase I. Five different video design formats were used in the creation of the instructional videos that students watched as homework in their flipped BEd classroom. They were: (a) PowerPoint (PPT) with Narration, (b) Internet-Accessed, (c) Screen Capture of an Application (App), (d) Explain Everything App and (e) Video Capture. Except for the Internet-Accessed videos and one of the PPT with Narration videos, the researcher created the instructional videos in this study. The content of each video design format presented a different mathematics topic. Table 3.2 summarizes the topic and video formats used in this study.

Table 3.2.

Summary of Video Design Formats and the Video Content

Topics (In sequential Order)	*5 video design formats*				
	PPT with Narration	Internet-Accessed	Screen Capture of App	Explain Everything App	Video Capture
Multiplication Strategies & Base 10 pieces	✓				
Fractions			✓		
Pythagorean Theorem		✓			
Decimals	✓				
Volume				✓	
Slope					✓

To add clarity to how the videos were delivered, Table 3.3 specifies the instructional day, number of videos created for each topic, and their corresponding time-length. It was possible for students to view more than one video in preparation for the flipped classroom because the class time was three hours long.

When focusing on the time component of an instructional video, it is important to recall that previous studies varied on the ideal length of a video. Raths (2012) suggested 1.5 minutes per grade whereas Guo et al. (2014) suggested six to nine minutes, however, their study was contextualized in a university online course (i.e., massive open online course). Given the uncertainty surrounding the ideal video length, the length of videos created for this thesis purposefully varied with the intention that students would comment on the different video lengths in the survey if they were problematic.

Table 3.3

Summary of Video Sets and Length of Videos

Day	Topics	Length of Video (min)
1	Multiplication Strategies	13
	Base 10 pieces	13
2	Introduction to Fractions	11
3	Using Pythagorean theorem to find the length of the hypotenuse	1
	Pythagorean theorem: General Case (formula)	2
	Pythagorean theorem: Worked example	2
4	Multiplication with Decimals	8
	Division with Decimals	9
5	Introduction to Volume	9
	Volume of Triangular Prisms	3
6	Slope: Part 1	14
	Slope: Part 2	5

In the following subsections, each video design format is described with details about the type of software used, amount of time required to produce this type of video, and rationale of the quality score assigned to each video design format. The researcher intentionally created low and high quality videos to provide students with a range of instructional videos. To rate the quality of each video design format, the researcher applied Kay's (2014) framework of effective video characteristics and cognitive load theory to assess the quality of each video.

PPT with Narration-1. The first video design format introduced to participants was a PPT with narration for the introduction to multiplication using base 10 pieces. The instructor of the course supplied the researcher with a highly visual and low text PPT presentation modelling good pedagogy (van de Walle, Karp, Bay-Williams, McGarvey & Folk, 2014), which provided the content for the video. Many slides included a series of object movements that animated a concept. The researcher audio recorded the explanation or instruction to support the content using a screen casting software, Camtasia ("Camtasia," n.d.). Camtasia was user friendly and offered many editing features to aid in creating a video that resembled a professionally developed video. One function that was used heavily in the creation of these instructional videos was the splicing function that allowed the researcher to edit speech making it smooth and free from stuttering or repetitions in speech.

The PPT with narration video design format was fairly time consuming but gave the creator more control over how the content was being presented, there in reflecting best practices in mathematics instruction. Several hours were spent modifying the PPT as well as recording and editing the narration so that the instructional video was pedagogically correct. The recording process took approximately three hours for a 13-minute video; however, the creation of the PPT slides took approximately 30 hours primarily due to adding animation (i.e., movement of base 10 pieces) to the slides.

The structure of the video began by stating the goals of the lesson and reviewing underlying concepts. The body of the video included a sequence of slides modelling how to multiply two single digit numbers using visuals such as an array diagram followed by the opportunity to pause the video and try a sample question. After the student attempted the sample question, students were instructed to press play to see the teacher's solution. Students were provided with a worksheet that contained the sample questions and white space for student work to be completed. Problems were sequenced so that they increased in difficulty as the video progressed. These videos concluded by summarizing the big ideas and connecting to the goal of the lesson.

Participants viewed this video design format on two separate occasions: introduction to multiplication and introduction to operations with decimals. For all other topics, a different video design format was used. The researcher chose to use the PPT with narration-style twice. It was presumed that this production style would be the most effective, because it facilitated the movement of objects to model ideal pedagogy and it was thought that many teachers were skilled in using PPT hence videos of this format may be more common in mathematics classrooms.

The PPT with narration-1 format had the highest quality score for all the video design formats used. The intrinsic load of the video content was given a score of three out of four, because the multiplication of two-digit numbers required students to compare two numbers and their size (two-digits) and apply the concept of multiplication.

Considering Kay's (2014) framework, the PPT with narration-1 format met all of the specific criteria. The overall quality score for PPT with narration-1 format was 18 out of a possible 20 points. Table 3.4 lists the subcomponent scores and total quality score for the PPT with narration format.

Table 3.4

PPT with Narration1 Quality Score

	Max Points	Score
Establishing Context	4	4
Effective Explanations	3	3
Minimizing Extraneous Load	4	4
Engagement	5	4
Intrinsic Load	4	3
Total Quality Score	/20	18

Screen capture of an app using Camtasia. The second video design format was the screen capture of an app. The purpose of this instructional video was to introduce participants to fraction terminology and to visually demonstrate the varying sizes of fractions with different denominators. Two fraction simulators that were freely available on the PhET (originally stood for Physics Education Technology) were selected and offered interactive simulations website provided by the University of Colorado Boulder campus (PhET, 2017). PhET website provided mathematics and science simulations that were based on extensive educational research and feature an intuitive game-like environment that engaged students through exploration and discovery (PhET, 2017). While in screen capture mode, the app is played, and the movements or simulation are recorded. The simulation starts with an introduction to the fraction simulation, which allowed the researcher to manipulate the numerator and denominator with different representations, such as fraction bars, circles, and cylinders. In the second part of the video, students were led through an activity to build a fraction using different representations as used previously. The building a fraction simulation was contextualized in a game environment. When the fraction was built correctly, music played and a happy face appeared. As questions were correctly answered, points were accumulated and moved on to the next level. Ideally, students would interact with this app themselves but, failing the accessibility to computers and the internet in the classroom, this video capture of the researcher manoeuvring through the app is a second alternative.

This video design format was far less time consuming, because there was no need to create an animation or simulation to demonstrate the content, rather, it was provided by an outside source. Approximately 45 minutes was needed to produce this video. Although this production style was time efficient, the quality of the pedagogical content was limited to the quality of the simulation software and the content that was presented in the app. In this case, since the PhET website provided a research-based simulation, the pedagogy was well grounded in theories of mathematics education, but the video did not allow the manipulation questions, pacing, sequencing, or video aspects of the app.

The screen capture of an app format received one of the lowest quality scores. One flaw to this format was the inability to annotate the video, which increased the extraneous load of the video. Therefore, the problems demonstrated on the video were not labelled, and the scaffolding could not be implemented. Also, in the background, there were unnecessary visuals that may have distracted the learner. For example, when the video was describing the numerator and denominator, the background had visuals of different fraction pieces that were not necessary for the explanation. This video was too long considering the low intrinsic load, and there were no opportunities for students to practice. These shortcomings reduced the video quality score. As noted, the intrinsic load of the video content was low considering that students only needed to count the number the pieces to match the correct pictorial representation of a fraction to the numerical representation. The total quality score of the screen capture of an app was 10 out of 20. Table 3.5 lists the subcomponent scores and total quality score for this video format.

Table 3.5

Screen Capture of an App Quality Score

	Max Points	Score
Establishing Context	4	3
Effective Explanations	3	2
Minimizing Extraneous Load	4	1
Engagement	5	3
Intrinsic Load	4	1
Total Quality Score	20	10

Internet-Accessed. Next, participants viewed three videos that were provided by Tapintoteenminds.com that focused on the Pythagorean theorem. Kyle Pearce, an experienced Canadian teacher who has earned Apple's Distinguished Educator award for his work on using iPads in the math classroom created the videos ("Pythagorean Theorem, n.d). The videos demonstrated the visual proof of Pythagoras's theorem and then presented examples that calculated the length of the hypotenuse using the visual proof. This set of videos were similar to the PPT with Narration video format but also included technical features such as a puff of smoke or the addition of music, which was previously found to be distracting (Kay, 2014). The rationale for experimenting with internet-accessed videos was to determine whether the participants in this study also found these additional features distracting.

One advantage of using these instructional videos was that they were very time-efficient. No time was required to develop the video. The only time commitment was in locating the resource on the Internet. Although this video design format was time-efficient for implementing the flipped classroom, the quality of the video was not ideal.

The quality score of the Internet accessed format was mid-range. Because the video was too short, the video did not provide background information or the key elements of the Pythagorean theorem prior to solving a problem. The video explanations were pedagogically sound, and the way information was presented minimized the extraneous load. However, the video was not as engaging, because the voice was monotone and formal. As mentioned, the video also included puffs of smoke and music, which can be distracting for the learner. Furthermore, the video did not provide students with the opportunity to practice. The intrinsic load of the video was high considering that Pythagorean theorem required students to measure each side length, square each side length, add both squared-lengths to determine the square of the hypotenuse and then take the square root to find the length of the hypotenuse. Because of this process, the intrinsic load of this video was rated at four out of four since students needed to relate four elements. Overall the quality score of the video was 15 out of 20. Table 3.6 lists the subcomponent and total quality score for the Internet-Accessed format.

Table 3.6

Internet-Accessed Quality Score

	Max Points	Score
Establishing Context	4	2
Effective Explanations	3	3
Minimizing Extraneous Load	4	4
Engagement	5	2
Intrinsic Load	4	4
Total Quality Score	20	15

PPT with Narration-2. PPT with narration-2 format was similar in structure to PPT with narration-1 format. The instructor of the course designed the highly visual low-text PPT, and the researcher used Camtasia to record the audio narration. Similar to PPT with narration-1, mathematical questions posed to the viewer were scaffolded so that the level of difficulty gradually increased. The video content demonstrated multiplication and division of decimals. The PPT utilized animations to move figures across the screen. For example, when decimals were divided by whole number (e.g., 0.6 / 3) pieces moved across the screen to form three groups to illustrate how many was in each group. Gifs (i.e., animated pictures) and pop culture references were added to some slides to infuse humour in the video. The major difference between PPT with narration-1 and PPT with narration-2 was the quality of the explanations and the intrinsic load of the content. The explanations in these videos were not as clear, because the narration did not consistently explain the reason for using each step. Also, the gifs and pop references may have been distracting for the learner. Additionally, the intrinsic load of multiplying decimals was high. Students needed to first consider the size of the two quantities (i.e., one-digit and then two-digit decimals), then consider the operation and represent them in an array diagram. Finally, students had to add all the pieces together to arrive at a final answer. If the two numbers being multiplied were smaller than one, the product is not intuitive, because the answer will be smaller than the original numbers. Typically when two whole numbers are multiplied, the product is larger than the original numbers; therefore, multiplying two quantities between zero and one in decimal form (e.g., 0.3 x 0.4) is intrinsically more difficult. The intrinsic load of these videos was given a four out of four. The overall quality score of the PPT with Narration-2 format was 17. Table 3.7 lists the subcomponents score and total quality score for the PPT with Narration-2 format.

Table 3.7

PPT with Narration-2 Quality Score

	Max Points	Score
Establishing Context	4	4
Effective Explanations	3	2
Minimizing Extraneous Load	4	4
Engagement	5	3
Intrinsic Load	4	4
Total Quality Score	20	17

Explain Everything App. The Explain Everything app is a screen casting, interactive whiteboard application that allowed users to animate, record, and collaborate ("Explain Everything," n.d.). The application is available for iPad, Android, Chromebook, and Windows devices. For the purpose of this thesis, the videos produced using Explain Everything did not use all of the possible features that the software offered. Instead, they featured a black background with real-time handwriting and audio narration. The content of the first video introduced linear dimensions such as length, width, and height as well as how to calculate the area and volume using the dimensions. The second video applied the general formula of volume (developed in the first video) to a triangular prism to develop students understanding of how to calculate the volume of this object and then represent the process in algebraic form. Before recording the video, the examples were prepared using Explain Everything slides, similar to a storyboard. During the recording, the researcher would add handwritten text while the solution was verbally explained. Often, the laser pointer was used to focus attention on a specific point on the screen, a process known as signalling. Neither of these videos featured a student problem or worked example; hence, the content remained mostly conceptual. The reason for not including a practice problem was to investigate whether students would identify a need for the inclusion of practice problems.

One disadvantage of this application was its lack of precision in splicing audio segments, which made it difficult to edit the audio on each slide. Therefore, if a mistake was made during the recording process, the user would have to re-record a certain section, lengthening the production time. Production time for this set of videos was approximately three hours in total.

The quality score of the Explain Everything format used in this study was low. As mentioned previously, this format mostly remained conceptual. There were no worked examples nor were there opportunities for students to practice, which influenced the establishing context and engagement subcomponent scores. The extraneous load of this format was high due to the recording of live ink annotation, which made it difficult to write clearly and produce a well-organized layout. The intrinsic load of the video was low, because the content only required students to recall the formula for a rectangular prism and divide the formula by two to derive the formula for a triangular prism. Therefore, due to the two interacting elements, the intrinsic load score was two out of four. Overall, this video was the least effective and the least professional looking. Table 3.8 lists the subcomponent scores and total quality score for the Explain Everything format.

Table 3.8

Explain Everything Quality Score

	Max Points	Score
Establishing Context	4	2
Effective Explanations	3	3
Minimizing Extraneous Load	4	2
Engagement	5	2
Intrinsic Load	4	2
Total Quality Score	20	11

Video Capture. The last video design format was the least demanding in terms of technological knowledge. This style used the video setting on an iPad camera to record a lesson of the teacher in front of the whiteboard. A PPT with embedded examples was created, and then the PPT was played while the teacher delivered a traditional classroom style lesson. The PPT and narration were recorded live using the iPad camera. The video was then edited by splicing together several short clips using iMovie, moviemaker software.

The content of this video was an introduction to slope and applied the distance-time graphs to calculate velocity. Production time of this video was approximately one hour to record and splice together the video. This video design format required a low-level of technology integration, because it relied on video recording technology that is widely used by the general population. This format differed from the other videos because of the visual presence of the teacher. This format was chosen, because it is assumed that teachers may try this format considering it required a low-level of technology.

The quality score of the video capture format was also low. Although this video included background information and articulated the key elements before beginning to solve a problem, problems were not labelled according to problem type. Regarding effective explanations, the video did not consistently explain the reason for using each step. Also, sometimes the writing on the SmartBoard was difficult to read and disorganized, which increased the extraneous load. Additionally there were no opportunities for students to practice, the pace of the video was too slow, and the video was longer than the ideal range, which decreased the engagement component score. The intrinsic load for calculating slope was given three out of four considering that students had to interpret the graph and compare two quantities to determine the slope. The overall quality score was 12 out of 20. Table 3.9 lists the subcomponent scores and total quality score for the Video Capture format.

Table 3.9

Video Capture Quality Score

	Max Points	Score
Establishing Context	4	3
Effective Explanations	3	2
Minimizing Extraneous Load	4	2
Engagement	5	2
Intrinsic Load	4	3
Total Quality Score	20	12

Data Collection

Phase I. The researcher developed nine instructional videos (as described above) to align with the content of the Mathematics for Teachers course. In six classes spread over two weeks, students were assigned one or two videos to watch each night for homework. In the following class, students completed the engagement survey at the beginning of class before any interaction with the teacher or peers. In total, six engagement surveys were administered to students.

Phase II. After students viewed all the videos, a survey was administered to students to collect their overall perceptions about the use of instructional videos and compare the video design formats. This survey was comprised of three sections. The first section had 29 Likert-type items measuring perceptions about instructional videos and video characteristics. The second section was an open-response item to solicit feedback on each type of video. The last section included one item to rate the video design format on a 5-point scale. Phase two was completed in class after viewing the last video and before students wrote their final exam for the course.

Phase III. To investigate teachers' perceptions on creating their own instructional videos, teachers were asked to provide feedback on their experiences of creating an instructional video. Data were collected during the final day of class using an open-ended survey that aimed at gathering their opinions and experiences. Ten questions were posed to gather information about teachers' experience. The first question surveyed the teachers' technological skills, and the second question captured the teachers' previous experience creating instructional videos. The remaining eight questions surveyed the teachers' perceptions related to creating instructional videos.

Instrumentation and Analysis

To measure the effectiveness of different instructional videos, three different instruments were constructed: (a) engagement with mathematics survey (b) overall feedback survey (c) teacher perceptions survey. This section discusses instrumentation and associated method of analysis.

Engagement with Mathematics Survey. The engagement questionnaire was adapted from Rimm-Kaufman's (2010) Student Engagement in Mathematics Scale (SEMS). The survey was designed to measure emotional, social, and cognitive engagement after having partaken a math class (Rimm-Kaufman, 2010). Rimm-Kaufman's 13-item SEMS survey had good internal consistency with Cronbach's alpha coefficient of 0.91, 0.98, 0.89 for the respective emotional (5 items), social (4 items) and cognitive (4 items) dimensions. The engagement questionnaire used in this study adapted eleven items from the SEMS survey to measure students' mathematical engagement while watching the video. Adaptations to questions were limited to replacing the phrase *in math class* with *while watching the video*. In addition to the 11-items adapted from the SEMS survey, four items were included to either measure student perceptions of the instructional videos or their preference of the flipped classroom model versus traditional mathematics homework. In total, this survey contained 15 items but three items (i.e., b, c, and f) were removed, because they did not load well with the other items as indicated in SPSS item-total statistics table. On this questionnaire, Cronbach's alpha coefficient was 0.7 or higher in each of the six times the questionnaire was used to measure student engagement with the six different video formats. Although the alpha coefficient was not as high as Rimm-Kaufman (2010) reported, the lower coefficient may be due to the smaller number of participants and the scale adaptations made to fit this study. Regardless, the reliability coefficient calculated for each of the six scales met the minimum requirement (Tabachnick & Fidell, 2012). Appendix A contains the full set of items surveying student engagement with the instructional videos.

The four-level response options for the statements presented on the questionnaire ranged from (1) no, not at all true, (2) a little true, (3) true and (4) yes, very true, as used by Rimm-Kaufman (2010). These descriptors were used to help students interpret the four levels consistently to improve overall accuracy. An even numbered scale was purposely selected, because a midpoint in this proposed scale would be ambiguous contributing to measurement error, and the survey topic was not controversial (Losby, 2012). Also, the ease-of-use provided by listing only four options was prioritized over the precision offered with five response options (Munshi, 2014), which is not necessary for this topic. To glean more information for the purpose of informing the Phase II survey, open response items were included to gain a greater understanding of student engagement and perceptions of instructional videos.

Quantitative analysis of engagement survey (students). Descriptive statistics were calculated for all items. The frequency and percent of response patterns were tabulated for all categorical and interval items. In addition, the mean and standard deviation were calculated for interval items.

A one-way repeated measure of the ANOVA was the preferred method to determine whether there was a statistically significant difference between the student engagement scores obtained after viewing each of the six instructional videos. However, due to the small sample size (n=12) combined with a few incomplete records, the less stringent non-parametric alternative, the Friedman Test, was selected (Pallant, 2010). There are three assumptions that underpin the use of the Friedman Test. The first is that one group of participants is measured on three or more different occasions. This assumption was met as the participants in this study were measured on six different occasions; each occasion was the time following viewing each instructional video. The second assumption is that the group is a random sample from the population and scores must be independent of other scores. In this case, the participants were not randomly selected, but the test is considered to be sufficiently robust to handle a quasi-random sample of the population of pre-service teachers. Since the engagement scores were measured at different times following viewing different instructional videos, they were considered to be sufficiently independent. The third assumption is that the dependent variable (i.e., engagement scores) be a continuous level. In this thesis, participants responded on a continuous 4-point scale. It is also important to note that the sample does not need to be normally distributed, which was the case in this thesis because of the small sample size.

The output for the Friedman Test generates the Chi-Square statistic, which summarizes how different engagement was between the six instructional videos. Other statistics generated in the Friedman Test are the degrees of freedom, which is equal to the number of variables being compared, less one. In this thesis, there are six variables and subtracting one, the degrees of freedom should be 5. Next the asymptotic significance is an approximate p-value. To be significant, the p value must be less than 0.05.

If the test is significant, then a follow-up test is needed to determine where the significant difference lies. In this case, the Wilcoxon test is then used to examine unique pairs within the set of six engagement scores. To control for Type 1 error across pairwise comparisons, the Bonferroni correction method was applied. The Bonferroni correction is a multiple-comparison correction used when there are several statistical tests being performed simultaneously (Goldman, 2008). In this case, the engagement scores for each pair of videos is being compared. To avoid false positives, commonly referred to as Type I errors, the alpha value needs to be set lower to account for the number of comparisons being performed (Goldman, 2008). The most conservative approach is to divide the alpha value for one test by the number of comparisons, which would be 15 in this thesis. Hence the alpha value used to test for significance following the Wilcoxon Test is 0.05/15 = 0.003. This Bonferroni method has been criticized for being too conservative (Goldman, 2008). Subsequently Holm's sequential Bonferroni correction (Holm, 1979) was applied because it was less conservative. Holm's calculated the correction using p/(n- number of pairs being compared + 1).

Overall feedback survey (students). The survey included three distinct sections: an open-ended response item soliciting feedback on useful features in each video, 21 selected response items surveying perceptions about using instructional videos, and an item to provide an overall ranking (1 to 5) of the videos. Appendix B lists the items used in the overall feedback survey. The creation of items for this survey was guided from participant responses on the engagement surveys from Phase I.

The qualitative section aimed to collect student perceptions on the performance of each video as an aid to learn mathematics. Participants were asked to comment on the features of the videos that helped them learn mathematics, such as level of difficulty, clarity of narration, instructions describing mathematics, opportunities to practice, and level of interactivity.

The quantitative section aimed at exploring the extent to which participants found various aspects of instructional videos as helpful in their learning. Participants recorded their responses to the 21 items using a 4-point Likert scale from strongly disagree to strongly agree. Items were developed based on Kay's (2014) theoretical framework for effective instructional videos and based on student responses from open-ended survey items in Phase I. The first aspect aimed at exploring if students preferred typed text versus hand-written text. The second aspect measured students' perceptions about the inclusion of production features that could be distracting, such as music or animations. Finally, the third aspect collected student perceptions on the inclusion of practice problems in an instructional video. Not all videos created for this study included practice problems for students to try so that students could experience videos with practice problems and videos without practice problems and comment on which aspects they found beneficial in their learning.

Finally, the third section of the overall feedback survey asked students to rate each production style on a 5-point scale based on their preference. The 5-point scale was used to give participants more precision in rating each video (Munshi, 2014). A score of one indicated, "This is NOT a good format for making instructional videos" and at the other end of the spectrum a score of five indicated "This is the best format for a video".

Student responses from the open-ended question on the overall survey were coded according to the framework proposed by Kay (2014). Themes were derived based on the coding patterns that emerged by comparing different video design formats and video characteristics of instructional videos. Themes that emerged from each video design format were also supported by descriptive statistics that were collected from student responses to the quantitative section of the overall feedback survey.

Teacher Perception Survey. The purpose of this survey was to gather teacher experiences related to creating an instructional video. Several questions were posed to collect teacher previous experiences with technology, the time devoted to creating an instructional video, the software used to create their video, and the challenges they faced with creating an instructional video.

Qualitative analysis of teacher reflection assignment. Teacher responses from the reflection assignment were coded to identify themes. Themes that emerged from teachers' responses were used to describe their experience creating instructional videos.

Summary

To address the research questions and gain a holistic understanding of instructional videos in a flipped classroom model two groups of participants were recruited. One group experienced the use of instructional videos as students, and the second group were teachers enrolled in a graduate course that created an instructional video. Data were collected over three phases using three survey instruments that measured engagement, student perceptions, and teacher perceptions. This study gathered both qualitative and quantitative data using open- and closed-response items. Phase one was analysed using a Friedman Test to identify differences between videos and then for those videos that were significantly different, their quality scores were compared. Phase two data was analysed drawing on Kay's (2014) framework to determine which features of instructional videos students perceived as helpful in their learning. Finally, data collected during phase three was coded to gain insight on the perceptions of teachers who created instructional videos. Each unique data set contributed to understanding the complexity of instructional videos used in a flipped classroom design.

CHAPTER FOUR

Findings

This chapter summarizes the data collected in the three phases of this thesis. Phase I findings included descriptive and inferential statistical summaries to report on the effectiveness of different video design formats and students' level of engagement with each instructional video. Phase II findings included student responses from the overall feedback survey identifying effective pedagogical characteristics of instructional videos. Descriptive statistics were also gathered from student evaluations of the videos identifying preferred video characteristics. These findings were then compared to findings from phase I. Findings from the open-response items were organized according to Kay's (2014) framework. Lastly, the qualitative responses in phase III, measuring the teacher perceptions about creating instructional mathematics videos, were analyzed using a theme analysis.

Phase I

Phase I findings were used to determine the extent to which quality videos promoted student engagement. The quality of the video design formats were rated using Kay's framework (16 points) plus an additional four points for the intrinsic load inherent of the video content. Table 4.1 lists the quality score for each video design format that was rated by myself and another practicing teacher.

Table 4.1

Rating of the quality of each video design format

Video Design Format	Quality Score (Max. 20)
PPT with Narration-1	18
Screen Capture of an App	10
Internet-Accessed	14
PPT with Narration-2	17
Explain Everything	11
Video Capture	12

Engagement, Descriptive statistics. Descriptive statistics were used to determine which video design format was the most and least engaging. Indicators of engagement were frequency in which they checked their cell phones while watching the video (i.e., a sign of engagement) or stopped and paused the video to do a practice question or rewind a video to watch it a second time (i.e., a sign of disengagement). Feedback from these three items revealed that students were most engaged while watching the PPT with Narration-1, the video that received the highest quality rating. Table 4.2 highlights this information.

Table 4.2

Level of Engagement

Item 5a, b, c: During the video how many times did you …	Group	More than once	Only once	Never	M	SD
Check your cell phone	PPT with Narration	3 (25.0)	3 (25.0)	5 (41.7)	1.82	0.874
	Screen Capture of App		4 (33.3)	8 (66.7)	1.67	0.985
	PPT with Nar. + Music	3 (25.0)	1 (8.3)	7 (58.3)	1.64	0.924
	Video Capture	1 (8.3)	2 (16.7)	6 (50.0)	1.44	0.726
	Explain Everything App		3 (25.0)	6 (50.0)	1.33	0.500
Press the pause button	PPT with Narration	8 (66.7)	1 (8.3)	2 (16.7)	2.55	0.820
	Screen Capture of App	2 (16.7)	1 (8.3)	9 (75.0)	1.42	0.793
	PPT with Nar. + Music	2 (16.7)		9 (75.0)	1.36	0.809
	Video Capture	2 (16.7)	2 (16.7)	5 (41.7)	1.67	0.866
	Explain Everything App	1 (8.3)	3 (25.0)	6 (50.0)	1.50	0.707
Rewind the video to review part of the video a second time	PPT with Narration	6 (50.0)	3 (25.0)	2 (16.7)	2.36	0.809
	Screen Capture of App	2 (16.7)		10 (83.3)	1.33	0.778
	PPT with Nar. + Music	1 (8.3)	1 (8.3)	9 (75.0)	1.27	0.647
	Video Capture		2 (16.7)	7 (58.3)	1.22	0.441
	Explain Everything App	2 (16.7)		8 (66.7)	1.40	0.843

Other items that reveal the PPT with Narration-1 video promoted students engagement were items 6a that ask students if they focused as hard as they could while watching the video (*M*=2.55, *SD*=0.934; 1=very true and 4=not at all true), item 6d that stated, watching a video was a great way to learn about math (*M*=3.18, *SD*=0.874), and 6h that asked if students enjoyed thinking about math while watching the video (*M*=2.45, *SD*=0.934). Although not all items strongly indicated students were seriously engaged with the videos, most items revealed that students were indeed engaged while watching the instructional videos.

Engagement, Inferential statistics. The 15 Likert-scaled items (i.e., items 6a to 6o) from the engagement survey were averaged to create a student engagement score for each instructional video format. Using these scores, the non-parametric Friedman test of differences among repeated measures was performed to determine whether one or more videos stimulated greater student engagement. Table 4.3 summarizes the mean rank scores generated by the Friedman test and Table 4.4 summarizes test statistics.

Table 4.3

Friedman Mean Rank

Production Style	**Mean Rank**
PPT with Narration1	5.64
Screencast of App	3.43
Internet-Accessed	2.57
PPT with Narration2	2.21
Video Capture	3.79
Explain Everything App	3.36

Table 4.4

Friedman Test Statistics

Variable	Statistic
N	7
Chi-Square	14.85
df	5
Asymp. Sig.	0.011

The Friedman test evaluating differences in medians was significant ($p<0.05$) and the Chi-Square value was 14.85. Kendall's W is a score between 0 and 1, where 1 indicates complete agreement between students. The score of 0.424 indicated fairly strong differences among the different videos.

Next, the post-hoc analysis was performed using the Wilcoxon signed-rank test tests to evaluate each pair of medians. Table 4.5 shows the *p*-values for this test.

Table 4.5

Wilcoxon Signed-Rank Test (p-values)

	PPTNar1	ScreenCap	InterAcc	PPTNar2	VideoCap	ExpEvery
PPTNar1		0.083	0.005	0.009	0.027	0.011
ScreenCap			0.091	0.209	1.000	0.168
InterAcc				0.308	0.206	0.102
PPTNar2					0.441	1.00
VideoCap						0.553
ExpEvery						

Based on the differences in the mean rank, the PPT Narration 1 video was much higher than the others hence there was a need to determine whether this video was statistically significant from the other five videos. This analysis would involve five comparisons for the Holm-Bonferroni adjustment. Table 4.6 shows how the Holm-Bonferroni adjustment was calculated. The null hypothesis is an outcome of no significant difference between instructional videos.

Table 4.6

Holm-Bonferroni Adjustment

p-values in order of small to big		Number of comparisons – 1_n		Modified p-value	
InterAcc: 0.005	X	5	=	0.025	*p*<0.05, reject null hypothesis
PPTNar2: 0.009	X	4	=	0.036	*p*<0.05, reject null hypothesis
ExpEver: 0.011	X	3	=	0.033	*p*<0.05, reject null hypothesis
VidCapt: 0.027	X	2	=	0.054	*p*>0.05, accept null hypothesis
ScrnCapt: 0.083	X	1	=	0.083	*p*>0.05, accept null hypothesis

Based on the findings presented in the Table 4.5, the difference between PPT Narration 1 and the Internet Accessed, PPT Narration 2 and Explain Everything videos was statistically significant.

Phase II

This section presents the findings related to student perceptions of video characteristics that were beneficial to their learning. Data collected in Phase II was obtained from the overall feedback survey completed by Phase I participants (i.e., students in the mathematics for teachers course). The overall feedback survey contained both open- and close-ended items. Open-ended items asked students to describe what features of the video were beneficial to learning. Close-ended items inquired about students' perceptions of beneficial video characteristics and the use of instructional videos as a tool for learning. The overall feedback survey also asked students to rate each video design format to confirm the results from Phase I.

Student responses to open- and close-ended questions on the overall feedback survey were organized according to Kay's (2014) framework.

Descriptive Statistics. To confirm which video design format students preferred, participants were asked to rate each format on a 1 - 5 scale, where a score of 5 represented "best format for a video" and a score of 1 was "not a good format" Table 4.6 provides the frequency of responses, as well as the mean and standard deviation for each video design format. According to the Phase I engagement score and the Phase II rating scale, student responses indicate that they preferred the PPT with Narration video design format. Almost all students (11 out of 12) assigned PPT with Narration format a score of 5 or 4, producing a mean score of 4.42 (*SD* = 0.90). The Screen Capture of App format scored the second highest mean score of 3.27 (*SD* = 1.19), which was only marginally higher than the lowest mean scores of 3.00 or 2.80. The frequency of student responses, standard deviations and mean of student ratings are reported in Table 4.7.

Table 4.7

Frequency Table of Student Rating of Video Design Formats

Video Design Formats	**5 "Best format …"**	**4**	**3**	**2**	**1 "Not a good format …"**	**SD**	**Mean**
PPT with Narration	7(58.3)	4(33.3)		1(8.3)		0.900	4.42
Internet-Accessed	1(8.3)	2(16.7)	6(50.0)	2(16.7)	1(8.3)	1.044	3.00
Screen Capture of App	2(16.7)	3(25.0)	2(16.7)	4(33.)		1.191	3.27
Explain Everything App	2(16.7)	1(8.3)	2(16.7)	3(25.0)	2(16.7)	1.476	2.80
Video Capture	3(25.0)		3(25.0)	2(16.7)	2(16.7)	1.583	3.00

Note: Scores in brackets are measured in percent.

At the time of creating the rating-scale item, the two PPT with Narration videos were intended to be identical in quality, thus, only one item was included to solicit student feedback about the quality of this video format. However, as noted previously, the two videos differed in quality since people with different levels of expertise developed them. Despite this shortcoming in item development, students still rated the PPT with Narration video superior over the other video formats, which corresponds to the rating given when contrasted with Kay's framework for evaluating instructional videos.

Student perceptions of video characteristics. The open-ended survey question asked students to describe the beneficial features of each video. Student responses were coded according to Kay's (2014) framework for creating video podcasts. Close-ended items focused on characteristics of instructional videos that were beneficial to learning as well as the effectiveness and use of instructional videos for teaching mathematics. Descriptive statistics produced from close-ended items were used to support qualitative findings. Findings are organized according to: general impact, establishing context, effective explanations, minimizing cognitive load, and engagement.

General impact. Almost all students (10 out of 12) strongly agreed or agreed (that instructional videos were an effective way to learn math (item 4k). Almost all students (11 out of 12) strongly disagreed that instructional videos not be used to learn mathematical concepts (item 4l). This negatively worded item can be positively stated to mean almost all students reported that videos can be used to learn mathematical concepts. In addition, most students (8 out of 12) strongly agreed or agreed that instructional videos helped them learn more (item 4c). Together, these results suggest students perceived instructional videos as an effective tool to learn mathematics. However, it is clear from the results in Phase I that students believed some mathematics videos were more effective than others.

Establishing context. Student responses indicated videos that lacked challenging content were less helpful. Responses were not targeted at one or two videos but distributed evenly between all of the videos. Most students (7 out of 12) commented that content was “too basic” or “too simple”. This concern is supported by direct evidence from the overall feedback survey where almost all students (9 out of 12) strongly agreed or agreed that instructional videos for challenging concepts are very helpful. Student 7 explained, “I found this video very repetitive. I’m not sure, but it may be because this is one of the few subjects I was already comfortable with.” Given that participants were post-secondary BEd students who were studying intermediate or elementary mathematical content, might explain why the content may not have been challenging for students. Therefore, appropriate problems should be selected that are congruent with students' abilities.

Student responses indicated that the alignment of the video content and classroom activities influenced their perceptions of the usefulness of the video. Two students reported their concern about the alignment of the video content and classroom activities for the Explain Everything video design format. Demonstrating concern about the video content, Student 1 commented that the video "did not prepare me for the classroom material," and Student 2 further explained, "more complicated concepts [needed] to be introduced if we're going to be doing work in class." These statements were contrasted with the PPT with Narration format (one of the preferred videos), where Student 5 disagreed by commenting, "I was able to take what I had watched and appropriately use it in class the next day." Comparing the two video design formats, the Explain Everything format did not contain opportunities for students to practice, therefore, students may have not seen the connection between the mathematical concepts explained in the Explain Everything videos and the application of the concept during the in-class activities. The challenge presented in this study was a need to better align the content and cognitive complexity with students' abilities, which was not entirely possible in this thesis given the relatively short turn-around time to prepare the videos and intense nature of the five week course. Evidence of a misalignment was found when only half of the students (6 out of 12) disagreed that the instructional videos prepared them for class. This finding suggests that student perceptions of the usefulness of the video was influenced by the alignment of the video content and classroom activities. It is important to note that video content and classroom activity alignment was absent in Kay's (2014) framework.

Effective explanations. Approximately 70% of student open responses (77 comments) related to the effective explanations component of Kay's (2014) framework. Students mentioned other components less frequently in their comments: establishing context (12 comments), cognitive load (13 comments), and engagement (19 comments). The majority of open-ended responses related to effective explanations component. This point suggests that this component is essential to creating an effective instructional video. Without effective explanations, it would be difficult for students to perceive the instructional video as helpful if the student cannot understand the content and follow the instructions. About 10% of student responses (8 comments) indicated that the videos were hard to follow, or they found it difficult to understand the topic. Although student responses did not specify which characteristic in particular caused the confusion, it could be due to the influence of one of the other components such as establishing context, cognitive load or engagement. Furthermore, the negative responses regarding effective explanations were evenly dispersed across the video formats, also suggesting that it could be other components such as cognitive load, or engagement that was causing students to find it difficult to understand.

Five out of twelve students commented that visuals were beneficial to learning. Visuals used to support the explanation of the concept were beneficial to learning as evidenced by Student 3's comment, "Illustrations gave me a much easier time to follow along." Also, Student 8 said, "The diagrams of the Base-10 squares helped my understanding. This video's concepts were new to me, and the information was easy to understand and thorough." Furthermore, Student 4 explained that visuals contributed to the explanation of the mathematical concepts by commenting, "Good visuals and clear instructions, contributed to my knowledge of adding/subtracting decimals*."* Student responses indicate that visuals helped them understand the material. As proposed by Kay (2014), student responses from this study confirmed that visuals can be used to clarify the explanations.

Another video characteristic that students valued was the summary recap feature, which was used to highlight the most important concepts. The summary recap feature was included in each video design format except for the Internet-Accessed format. The majority of students (11 out of 12) strongly agreed or agreed that a summary recap at the end of the video helped students retain what they learned (item 2m). Along the same line of inquiry, the majority of students (10 out of 12) strongly agreed or agreed that the summary recap helped them remember the major concepts learned in the video (item 2a). Students' perceived summary recaps as beneficial to learning, because it highlighted the most important concepts discussed in the video and helped student retain the information. Summary recaps were absent from Kay's (2014) framework.

Minimizing cognitive load. Student responses indicated that animations were helpful features of instructional videos. Student 7 commented, "I liked seeing the pieces of the fractions and the ability of the instructor to move the pieces around." Also, Student 8 described, "Dragging the pictures to match pictures [of fractions] and matching the numbers and vice versa*"* was a helpful characteristic. Responses suggest that instructional videos that utilize technology to manipulate figures and diagrams were more effective than static images. This concept was absent from Kay's (2014) framework.

Student responses were negative when focusing on the layout and written text that appeared on the Explain Everything video format. Student 8 commented, “It was kind of hard to read the written text.” Furthermore, the majority of students (8 out of 12) strongly agreed or agreed video creators should avoid handwriting because it is too messy (Item 2i). Conversely, the majority of students (7 out of 12) strongly agreed or agreed that handwriting on the video was just as good as typed text or numbers (item 2d). These mixed results suggest that extra caution needs to be applied to write/print clearly when creating instructional videos with handwritten text. Handwritten text was only used in the Explain Everything format. A finger pressed onto the tablet screen was used to write the steps and annotate parts of the video. Perhaps the use of a stylus would have made the writing clearer. This finding supports the inclusion of clear written text in Kay’s (2014) framework.

A well-organized layout was another video characteristic that minimizes the cognitive load of the video. Student responses suggested the layout of the Explain Everything format increased the cognitive load of the video. Student 6 commented, “I felt this video was a bit sloppy and boring.” Student 4 noted, “Presentation was not very concise. A bit messy.” Regarding the layout of the PPT with Narration format, Student 3 commented, “The entire format of this video was my favorite out of all the videos. The structure helped me to learn.” Student responses suggest that they preferred the organized structure and layout offered in the PPT with Narration format, and not the Explain Everything format. This finding supports the inclusion of a well-organized layout in Kay’s (2014) framework.

Engagement. The most prominent finding was that students indicated a need to include practice problems; this point was an essential element of instructional videos. Nine out 12 students strongly agreed or agreed that videos were more beneficial if they included practice problems for them to try (item 2l). Along the same line of inquiry, the majority (10 out of 12) of students strongly agreed or agreed that effective instructional videos used to teach math must include practice problems for the viewer (item 4e). Furthermore, almost all students (11 out of 12) strongly agreed or agreed that being verbally instructed to pause the video and try an example, referred to as segmenting, was a helpful feature (item 2c). Some formats did not include opportunities to practice (e.g., Internet-Accessed, Screen Capture of an App and the Explain Everything format). Regarding the Screen Capture of an App format, Student 1 commented, "I felt this video was incredibly slow, watching someone else do several fraction questions dragged on. I would have preferred doing them myself." Student 2 also commented, "Easy and informative but no opportunity to practice." Student responses regarding the Explain Everything format also concluded that videos without student practice problems were "boring" or have "no interaction" as commented by Student 6 and 4 respectively. Regarding the Internet-Accessed format Student 2 commented, "Good narration but no opportunities to practice" and Student 4 explained, " [The video was] easy to understand but a little boring." Student responses indicated videos that did not provide students with the opportunity to practice were less engaging. Based on the responses from the students, it is absolutely critical mathematics instructional videos include problems for students to practice and that the videos verbally instruct students to pause and try the problem. These findings confirm the inclusion of opportunities to practice in Kay's (2014) framework.

Another theme that emerged from student responses was the visual presence of the teacher in an instructional video. Some students responded positively to the visual teacher-presence included in the video capture format. Student 3 noted, “I enjoyed the switch up between the illustrations, a teacher, and the ability to pause.” Student 2 also commented, “Very informative. Nice component with the lecturer there.” Students responded that they enjoyed the video capture format, because the teacher presence created a familiar classroom environment with the ability to pause and rewind the lesson. Although some students enjoyed the teacher presence in the video, 4 out of twelve students rated the video capture video as a 2 or a 1 on a 5-point scale, where a score of 1 indicated “not a good format” Student responses related to the visual presence of the teacher were mixed.

Summary. Students reported that instructional videos were an effective way to learn mathematics. Of the five video design formats, students indicated that the PPT with Narration format was the most engaging. Regarding video content, students reported that problems should be aligned to the in-class activities and course expectations. Furthermore, student responses indicated videos that lacked challenging content were less engaging. According to student responses, effective explanations were essential to learning. Specifically, student responses indicated that explanations supported by visuals were beneficial to learning. Another video characteristic that students perceived as beneficial was closing the video with a summary recap. Student responses indicated that animations, a well-organized layout, and clear handwritten text were beneficial to learning and minimized the cognitive load of the video. The most prominent finding was that mathematics instructional videos must include practice problems for students to try.

Furthermore, students indicated that it was helpful for the narrator to verbally instruct the students to pause the video to try the example. Student responses were mixed regarding the video capture video design format that featured the teacher in front of a whiteboard.

Phase III

This section summarizes teachers' perceptions on the use and development of instructional videos. Teachers were recruited from a MEd mathematics cohort that created instructional videos as one of several assessment tasks in the course. Data collected in Phase III were obtained from a survey of the teacher experiences in creating their instructional video. The survey consisted of open- and close-ended items. Teacher responses to open-ended questions were coded to identify themes. The two major themes identified were (a) instructional videos were valuable learning tools and (b) video creation is challenging.

Instructional videos are valuable learning tools. When prompted to describe their thoughts, reflections, or recommendations about creating videos for mathematics instruction, eight out of twelve teachers reported they believed instructional videos were valuable. For example, Teacher 11 described the benefits of instructional videos by commenting:

> Videos are a great way to engage students. They offer another way to reach students to help with their learning and understanding. I'm certain that we as educators are just starting to see the benefits of using videos to help with instruction.

The value of videos was further explained by Teacher 9 who noted, "Videos are valuable learning [instruments] for students as they can learn at their own pace." Furthermore, two teachers reported that students were not the only ones benefitting from the process of creating an instructional video. Teacher 3 recognized the potential benefit of instructional videos for parents when he commented, “It can be fun! You get a great resource that can be reused by the teacher, as well as the students and their parents. Don’t be afraid to try something new!” Also, Teacher 8 shared her enthusiasm for creating videos and explained the benefits to her own teaching practice by commenting,

> It was such a beneficial process. I thoroughly enjoyed the project. I was apprehensive at first, but haven’t felt so proud of something I have created in a long time. Loved it! Would love to implement into my practice on a regular basis.

Other teacher responses indicated that instructional videos were valuable to students, and parents and benefited the teacher’s own pedagogical practice. Teachers’ recognition of the opportunity for instructional videos to benefit their own teaching practice is further explored in the following sections, where teacher responses indicated that collaboration was a useful strategy to assist in the challenging task of video creation.

Challenging aspects of video creation. Although many teachers believed that instructional videos were valuable tools for teaching and learning mathematics, teachers also highlighted some challenging aspects in creating instructional videos. The first concern was the amount of time required to record pedagogically sound narration. Second, teachers reported that using and selecting the technology was also a challenge.

Recording pedagogically accurate narration. Teacher responses (6 out of 12) indicated that recording pedagogically sound narration was the most time-consuming aspect of video creation. On average, teachers estimated it required 11 hours to record the narration (M_{time} = 11.56; *SD* = 8.56). In response to the question, “what was the most challenging aspect of creating your video?" four out of twelve teachers noted the heavy time investment in recording the narration. For example, Teacher 2 responded that the most challenging aspect of video creation was "Questioning whether your video was pedagogical [*sic*] sound. The time investment and number of retakes needed." Also, Teacher 6 claimed the most challenging aspect was "Creating the narrative so that it flows well and is pedagogically sound." Responses suggest that teachers were reflective and critical of the narration, or explanation of the mathematical concepts presented in their videos. Teachers perceived the recording of the narration as a challenging and time-consuming process; however, recording the audio for an instructional video provided teachers with the opportunity to reflect on the pedagogy of their mathematical explanations.

Although many teachers noted this heavy time investment, Teacher 5 commented, "It will take a lot of time upfront, but the product is worth it. And the process should get quicker with more experience." Ten out of twelve teachers reported that it was their first time creating an educational video and estimated that it took about 40 hours to create their video ($M = 40.33$; $SD = 21.19$). Given that it is not possible for teachers to devote this amount of time to prepare a video for every class, two teachers suggested collaboration across schools as a possible solution to create these valuable, yet time-consuming resources. To address this concern, Teacher 5 suggested teachers of the same course collaborate to create a bank of videos. Teacher 5 explained, "Videos are very powerful when done well. A teacher should not think they need to create a video for everything since it is so time consuming." Teacher 4 was also concerned about the time required to create quality videos. Teacher 4 suggested, "The Department of Education should take on some responsibilities and help teachers to create more high-quality videos." Teacher responses indicate that the time required to create a pedagogically sound video was not ideal for teachers to integrate this technology on a daily basis.

Learning and using the technology. Learning and using the technology was also challenging for teachers. In response to the question, "what was the most challenging aspect of creating your video?" six out of twelve teachers reported that the technology posed the greatest challenge. Teacher 2 reported the most challenging aspect was "Exploring the new technology and trying to make it do what I wanted it to." Also, Teacher 9 commented, "For me, the most challenging aspect is the technology, such as how to create slides in Camtasia, add special effects, record voice-over, share and upload the video to Youtube." Furthermore, Teacher 11 explained it required practice to use multiple computer applications and follow the script. Teacher responses indicated that learning and using the technology required to create an instructional video was challenging.

Another challenge expressed by teachers was the limited capabilities of software. When teachers were asked what they would do differently if they were to create another video, half of the teachers (6 out of 12) responded that they would change some form of the technology used. Teacher 2, Teacher 3, and Teacher 8 indicated that they would have changed the technology to improve the video's aesthetic appearance. More specifically, Teacher 3 commented, "Find better software that would allow me to create more modern effects and transitions." Teacher 8 commented they would like to become more familiar with the capabilities of the software in order to "add a few new finishing touches… such as having my mouse cursor magnified in Camtasia." Also, Teacher 2 desired to use software with better animation effects than PowerPoint and wanted to use a software like Explain Everything, that allowed virtual ink annotation. Teacher 11 also noted the challenge in choosing between software that offer strong visual features and software that supported graphing calculators. Only a minority of teachers suggested that they believed it was important to include a visual of the teacher to engage students. Two of the 12 teachers indicated that they preferred to record their lesson in front of the whiteboard using the low-technology video capture design format. Teacher 4 commented, "If I am creating a video for my own students, I would revert to my initial style: create power point and film myself going through the lesson." Teacher 5 also indicated that she preferred video capture and explained, "I like to have myself in front of the camera so that my students see a familiar face." Teacher responses indicated that selecting the technology that offered a range of features to apply pedagogical practices *and* produce a professional-quality product was a challenge. Since teachers experienced difficulty in creating instructional videos, their advice on how to approach the task of video creation was immensely valuable to other teachers who wished to create instructional videos of their own.

Advice on how to approach the task. The reflection survey asked teachers to consider what advice they would you give to others who were interested in creating an instructional video. First, four of the twelve teachers recommended beginning by viewing instructional videos online. Teacher 7 suggested, "I would advise other teachers to spend some time looking at videos online related to the content they are interested in creating. Take notice of what you like about certain videos and also what you don't like." Teacher 8 also suggested, "Watch other instructional videos on your topic first. This will give you ideas on what to do or not do." Furthermore, Teacher 9 suggested, " look at different examples of teaching videos and read at least an article about flipped classroom to get an idea of the purpose of flipped videos and different formats of videos." The responses indicated the process began by exploring different formats of videos and to be critical of other videos, noting what to do or not to do.

Second, four of the twelve teachers noted that careful planning that was needed prior to recording. Two teachers emphasized the importance of creating a storyboard (e.g., a collection of sequenced "slides" with visuals) before creating and recording an instructional video. Teacher 9 claimed that "storyboarding is critical in planning a good video." After the storyboard was created, teachers indicated that preparing a script was important. Teacher 6 and Teacher 8 emphasized the importance of writing a script before you record. Teacher 6 commented, "Prepare a script to aid in your delivery. This helps immensely." Also, teacher 8 advised,

> Create your slides. Write a script of what you would like to say. Practice, practice, practice. It will take many takes. When recording yourself, be sure to pause and not talk too much. Your voice should match the animations on the screen.

As previously noted, teachers reported it took on average 11 hours (M = 11.56; SD = 8.56) to record the narration, indicating that the narration process was time-consuming. Reflecting on the lengthy process involved in creating instructional videos, teachers advised to write a script before the recording. It is clear from teacher responses that careful preparation prior to recording the video was helpful in creating a quality video. Teacher responses also indicated that collaboration was also helpful to create quality videos.

Collaboration is key. Five of twelve teachers reported collaboration was crucial for creating a quality instructional video. Teacher 2 explained, "It is valuable to create videos for your students, but they should be of high quality. You should seek help from others that are more skilled in other areas. Collaboration is very helpful in creating videos." Also, Teacher 9 noted that asking for feedback from colleagues was very helpful during the video preparation. Teacher 9 explained, "It's helpful to have someone else look at it from a different perception." Teachers mentioned collaborating with experts as well as colleagues, and students, indicating that creating an instructional video provided teachers the opportunity to get feedback on their teaching.

Summary. Collectively, these findings provide evidence to report that instructional videos are a valuable learning resource. Two aspects of video creation that posed a challenge for teachers were recording the narration and selecting the appropriate technology. Teachers reported that preparing a script and storyboard before recording the video was very helpful. Also, responses indicated that collaboration and feedback was critical to producing a quality video.

CHAPTER FIVE

Discussion

This final chapter begins by weaving the literature of instructional videos with the findings presented in the previous chapter to respond to the three research questions posed in this thesis. The response to the first research question begins with a review of the hypothesis followed by a discussion on how the design of various videos influenced student engagement. This section concludes with a critical look at previous flipped classroom research that reported no significant difference in student achievement.

The discussion on the second research question focuses on students' perceptions of video characteristics that were helpful for learning. This section begins with a synthesis of findings related to students' perceptions of the use of instructional videos followed by a discussion of video characteristics that students identified as beneficial to learning. The discussion concludes by summarizing video characteristics that confirmed findings from previous research, as well as, outlining new video characteristics that were absent from the literature.

The discussion of the third research question focuses on teacher experiences creating an instructional video. A review of findings related to teacher perceptions and challenges of instructional videos are summarized. This section concludes by contextualizing teacher experiences and challenges creating instructional videos through the Technological Pedagogical Content Knowledge (TPACK) framework.

The conclusion to this thesis proposes a pedagogical framework of effective instructional videos and summarizes teacher experiences in creating instructional videos.

This section also presents two areas of further research regarding effective video characteristics and provides two implications for practice. Lastly, the strengths and limitations of this study are also discussed.

Research Question 1: To what extent do different video design formats promote student engagement?

The permeation of technological advancements into society and subsequent slide into classrooms has prompted educators to experiment with the flipped classroom model of instruction (Bishop & Verleger, 2013; Chen et al., 2014; Groff, 2014). The flipped classroom model is a form of blended learning that integrates technology to deliver the instruction outside of the classroom to encourage more student-centered activities in the classroom (Chen et al., 2014; Kim et al., 2014; Love et al., 2014). Overall, prior research reported that students' perceptions of the flipped classroom model were positive and students were engaged in their learning in this environment (Lloyd & Robertson, 2012; Love et al., 2014; Moore & Smith, 2012; Rackaway, 2012; Sahin et al., 2014; Thomson et al., 2014). One of the key components of the flipped classroom is the use of an instructional video to deliver instruction (Gilboy et al., 2014; Guerrero et al., 2015; Kennedy et al., 2015; Love et al., 2014; Mason et al., 2013; Rossi, 2015; Sahin et al., 2014; Wong et al., 2014; Yong et al, 2015), yet, the pedagogical details of how instructional videos ware constructed were absent from research (Kay, 2012). Therefore, the purpose of this aspect of the thesis was to determine if the video design format made a significant difference in student engagement.

Given that quality instruction has been shown to promote student engagement (Kohl, 1994; Schelchty, 2002), it was hypothesized that video design formats that utilized best instructional practices would be of higher quality and would subsequently promote student engagement compared to lower quality videos. To test this hypothesis, six video design formats, of varying quality, were created for a BEd course, which were delivered in the context of the flipped classroom model. Self-reported level of engagement was measured using 15 Likert-scaled items. Using these measures, the non-parametric Friedman test of differences among repeated measures was conducted to determine whether one or more video design formats stimulated greater student engagement. The Friedman test evaluating differences in medians was significant, $\chi^2(1, n=7)=14.85$, $p<0.05$ and Kendall's coefficient of concordance was 0.424 indicating a fairly strong differences among the different videos. Follow-up pairwise comparisons using a Wilcoxon test and controlling for Type I errors across these comparisons at the 0.05 was completed. Differences in the mean rank revealed that the PPT Narration-1 video was much higher than the other videos, hence, there was a need to determine whether this video was statistically significant from the other five videos. Findings revealed that the PPT with Narration-1 instructional video was statistically significantly different from PPT with Narration-2 and the Explain Everything videos.

When comparing differences between the PPT with Narration-1 video and the two listed above, three major distinctions were noted. First, the structure and design between the PPT with Narration1 and PPT with Narration-2 were almost identical. The main difference between the two formats was the pedagogy. The PPT with Narration-1 video was created and narrated by an expert in mathematics education whereas a novice instructor (i.e., myself) created and narrated PPT with Narration-2. This difference in expertise influenced the pedagogy in the videos where PPT with Narration-1 was clear and easy to understand and the PPT with Narration-2 was reported to be more confusing and the pictorial animations were not as well crafted. This finding provides evidence that the platform in which the video was created comes second to the quality of pedagogy. Similarly, the Explain Everything videos developed by myself and focused on volume of regular shapes, were also reported to be confusing. The statistically significant difference between these videos indicates that the quality of pedagogy in the video had a significant impact on student engagement. These observations suggest that the pedagogical content knowledge (PCK) had a major impact on the quality or success of the videos. Thus, educators who have more pedagogical content experience are more likely to create more engaging videos.

The second interpretation to this statistical significance is connected to opportunities for students to practice during the video. The Explain Everything video did not contain opportunities for students to practice mathematics while the PPT with Narration1 provided students with multiple opportunities for students to practice. Students' responses from Phase II findings indicated that almost all students (11 out of 12) agreed or strongly agreed that the opportunity to practice the math was helpful. Furthermore, ten out of twelve students indicated that instructional videos used to teach mathematics must include practice problems for the viewer. These findings support the argument that the Explain Everything video was significantly less engaging most likely due to a combination of problems related to the absence of good pedagogical instruction and opportunities for students to practice. This finding supports Kay's (2014) research who reported that nearly two-thirds of students in her study indicated they liked completing the student practice problem. Student practice problems help segment the video into manageable sections that reduce the cognitive load of the learning experience (Ibrahim et al., 2012). Segmentation is a pedagogical strategy that is derived from multimedia learning (Ibrahim et al., 2012), thus, it can be considered as a component of technological pedagogical knowledge (TPK). Segmentation aids students in processing one cluster of related information at a time before moving onto the next segment of relevant information, which explains why students found this feature beneficial. Therefore, findings from this study are aligned with previous research that calls for the inclusion of student practice problems in instructional mathematics videos. Furthermore, the findings suggest that technological pedagogical knowledge (TPK) integrated in the design of the instructional video promoted student engagement.

The third major distinction was that the Explain Everything video did not utilize the technology to enhance the mathematics pedagogy when compared to the PPT with Narration-1 video. For example, the PPT with Narration-1 video used animation features provided by PowerPoint to improve the explanation and demonstration of the mathematics content making the video savvy. Explain Everything did not contain the same technical features to enhance the explanation or demonstration of the mathematics pedagogy. The software, or use of technology, only captured the lesson digitally (similar to writing on a whiteboard) and did not necessarily improve the instruction of the mathematics content. Although the Explain Everything software has more dynamic features, those advanced features were not applied to the creation of the mathematics video.

As previously reported, there was no significant difference between the Screen Capture of an App and the Internet-Accessed formatted videos. The mean scores for these two videos were closer to the PPT with Narration-1 video and it is possible that, with a larger sample size, these two video formats that also utilized technology may have generated a significant difference. In sum, the findings suggest that technological pedagogical knowledge (TPK) integrated in the design of the instructional video promoted student engagement.

As hypothesized, pedagogical characteristics related to technology (TPK) and content (PCK) were significant factors in the design of instructional videos that promoted student engagement. Therefore, instructional videos that apply accurate and well-explained pedagogical strategies, while simultaneously utilize technology to enhance the instructional delivery of the content, are more likely to promote student engagement.

The impact of video quality on student engagement in mathematics suggests that previous research that reported decreased motivation and no significant difference in achievement (Kennedy et al., 2015) or reported increasingly negative perceptions towards the use of videos (Guerrero et al., 2015) may have used poor quality videos lacking in pedagogical accuracy, clarity, and technological features that compliment the pedagogy. Unfortunately, Kennedy et al. (2015) did not describe the quality of the videos used for their study other than report using Explain Everything to create videos for a calculus course. Furthermore, the lack of detailed video description suggests that the researchers did not apply a theory-based framework in the development of their instructional videos. If the instructional videos did not utilize a pedagogical framework, then it is likely that the videos used in Kennedy et al.’s (2015) study were in poor in quality, which may account for students' and instructors' dissatisfaction with the flipped classroom model as an everyday approach.

Similarly, in Guerrero et al.'s (2015) study, they reported that a flipped classroom approach was not the preferred instructional approach given that both the instructor and the students displayed growing dissatisfaction with the use of videos. Although these researchers did not attribute this dissatisfaction to the quality of the videos, based on the findings from this study, it is quite possible that the dissatisfaction was the result of poor quality videos rather than the flipped classroom model. Another study reporting a poorly received flipped classroom model was Wong et al. (2014). These researchers suggested that the flipped classroom model may be better suited for particular content or courses with substantial curriculum that requires more time to deliver. However, this conclusion is also questionable considering that the flipped classroom model was only implemented three times in a semester, and the videos were drastically lengthy (i.e., 90, 80 and 130 minutes), considering the recommended length is about 6–9 minutes (Guo et al., 2014). If the videos used were this lengthy, it is unlikely that the videos were created with pedagogical aspects in mind.

In sum, the quality of video designs has a large effect on student engagement and in turn, the effectiveness of the flipped classroom model. Pedagogy must be accurate and well communicated. Complimenting these well designed instructional videos with technological features to enhance clarity is key to promoting student engagement. To further investigate the pedagogical characteristics of quality instructional videos, students' perceptions were analysed. The specific characteristics of the videos that students perceived as beneficial to their learning are discussed in the following research question.

Research Question 2: To what extent do students perceive the pedagogical characteristics: establishing context, effective explanations, minimizing the cognitive load, and engagement helpful in their learning?

The second research question posed in this study investigated students' perceptions of instructional videos and video characteristics that were beneficial to learning. As discussed above, the quality of the instructional video had an effect on student engagement. Examining student perceptions of video characteristics was intended to identify other characteristics or nuances of instructional videos that students believed influenced their learning such as establishing context, effective explanations, minimizing the cognitive load, and overall engagement.

Students' perceptions of video characteristics. Previous research reported that students viewed instructional videos positively (Gilboy et al., 2014; Kay, 2014; Long et al., 2016; Love et al., 2014; Roach, 2014; Sahin et al., 2014); thus, it was hypothesized that students would perceive instructional videos as a useful tool for learning mathematics. Although student perceptions of instructional videos and their usefulness have been previously studied (Gilboy et al., 2014; Kay, 2014; Long et al., 2016; Love, 2014; Roach, 2014; Sahin et al., 2014; Yong et al., 2015), research has yet to identify which characteristics make one instructional video better than another. Considering that the purpose of instructional videos for the flipped classroom model is to deliver instruction, it was expected that pedagogical techniques would positively influence students' perceptions of instructional videos. Therefore, it was hypothesized that students would perceive video characteristics that were rooted in accurate and well-communicated pedagogy as beneficial to learning.

This section begins with a summary of the students' overall perceptions on the effectiveness of instructional videos as a tool for learning mathematics. On the seven items, students responded positively to the use of instructional videos as a tool for learning mathematics. Almost all students (10 out of 12) agreed or strongly agreed that instructional videos were an effective way to learn mathematics. This finding is echoed in previous research that reported watching videos were an effective tool for learning (Kay, 2012; Lloyd & Robertson, 2012; Moore & Smith, 2012; Rackaway, 2012; Thomson et al., 2014). Furthermore, the majority of students (8 out of 12) agreed or strongly agreed that instructional videos helped them learn more. Love et al. (2014) also reported that students learned significantly more from the videos compared to the traditional approach of teaching mathematics. In addition to students agreeing with the statement that instructional videos were an effective way to learn mathematics, almost all students (11 out of 12) strongly *disagreed* that instructional videos should be avoided. This finding provides evidence that instructional videos were not detrimental to learning. In contrast, one study was found that reported negative aspects of instructional videos; however, empirical evidence was not provided to support this conclusion (Yong et al., 2015). These researchers concluded that instructional videos might be better suited for certain topics, but, if instructional videos were good quality, any topic should be suitable; the difficulty may be that some topics may involve more creative or innovative efforts in addition to the allotment of additional time.

Similar to the finding in this study, Yong et al. (2015) reported that video quality was a factor influencing student engagement. These researchers reported that some students (no exact number was identified) claimed they could not learn from the videos and became frustrated and confused (Yong et al., 2015). Furthermore, some students specifically complained about the pacing of the video and found it difficult to focus while watching the videos (Yong et al., 2015). Although Yong et al. did not allude to a poor video quality, based on the findings from this thesis and the comments made by students in Yong et al.'s study, it is possible that the quality of their videos was low.

As synthesized above, students generally held positive perceptions towards instructional videos used in the flipped classroom. However, only this study utilized different video platforms and presented a number of videos with varying quality, allowing for purposeful examination of characteristics which make one video better than another.

Establishing context. The establishing context component of Kay's (2014) framework ensures that appropriate problem selection, clear problem label, background information related to the content, and key elements are discussed before beginning to solve a problem. Student responses from this study indicated appropriate problem selection that is reflective of the in-class activities were beneficial to learning. When considering the usefulness of each video, seven out of 12 students commented on the video difficulty level. Two students (out of 12) indicated that the Screen Capture of an App format (fractions content) was too simplistic, thus, the selection of questions or the presentation of information was not an appropriate problem selection. Additionally, three out of 12 students commented that the Explain Everything format (introduction to volume content) was also too easy and simple, which, once again, indicates that students are aware of the need for appropriate problem selection. Although the topics in these two videos were intended to provide background information, it appears that this background information was not needed or could have been reduced. Furthermore, direct evidence from the overall feedback survey supported this finding where the majority of students (nine out of 12) agreed or strongly agreed that instructional videos for challenging concepts were very helpful. Therefore, student responses indicate the difficulty level of the video content was not challenging enough for students to consider the video useful.

A factor that may have influenced this finding is the fact that post-secondary students in this study were learning content that they were previously exposed to in upper elementary or middle school. The video content of the course was specifically chosen considering that BEd students who were required to take the course may be teaching this level of content. Therefore, a goal of the course was to model best teaching practices of mathematics content considering that BEd students may be required to teach this level of mathematics in the future. Considering that mathematics is typically considered to have a high intrinsic load (Chinnappan & Chandler, 2010), this finding suggests that teaching mathematics through instructional videos is appropriate. Additionally, 10 out of 12 students indicated that overall instructional videos are an effective way to learn mathematics. Along the same line of inquiry, students also mentioned that problems selected for the video should be congruent to the in-class activities.

Student responses indicated that the alignment of the video content and classroom activities influenced their perceptions of the usefulness of the video. Demonstrating concern about the video content, Student 1 commented that the video “did not prepare me for the classroom material,” and Student 2 further explained, “More complicated concepts [needed] to be introduced if we’re going to be doing work in class.” It is possible that the classroom activities and videos were not completely aligned, because the researcher, who chose and developed the videos, did not instruct the course. Half of the students (six out of 12) disagreed that the instructional videos prepared them for class. This finding suggests that student perceptions of the usefulness of the video are influenced by the alignment of the video content and classroom activities. This indicator of an effective instructional video is absent from Kay's (2014) framework, because the purpose of the framework was not developed for the flipped classroom specifically, but for instructional videos in general. Yet, it is certainly worth considering the in-class activities when developing the video so that students can see the connection between their assigned homework (i.e., the video) and what is expected of students in-class. Thus, the congruency of video content and in-class activities is an important factor that influences student perceptions of instructional videos.

Synthesizing these findings suggests the difficulty level of the content presented in the video as well as its alignment with the in-class activities is an important characteristic that influenced student perceptions of the usefulness of the video. These characteristics are absent from Kay's (2014) framework but should be added as indicators of effective instructional videos used in a flipped classroom context.

Effective explanations. Effective explanations component argued that problems should be broken into meaningful steps, and the reason for using those steps should also be explained. This component draws most heavily on theories of effective pedagogy. In addition, visuals can be utilized to enhance the verbal explanation, a process known as matching modality (Brame, 2015). Approximately 70% of student responses from this study were related to the effective explanations component of Kay's (2014) framework. Other components were mentioned less frequently in student responses suggesting that effective explanations was especially important to the quality or usefulness of the video. Given the importance of effective explanations in creating quality instructional videos, studies exploring the utility of instructional videos in the flipped classroom should solicit student feedback in this area. Unfortunately, neither Yong et al. (2015) nor Kennedy et al. (2015) solicited feedback from students regarding the quality of their instructional videos. Student perceptions in this area would have added insight to interpret their result of no significant difference in learning outcomes between the control and experimental groups. For this reason, it is difficult to understand the contextual features of their flipped classroom design that may have influenced their findings.

Student responses from this thesis also confirmed that visuals were useful in enhancing the explanations. Five out of 12 students commented that visuals were beneficial to learning as evidenced by Student 3's comment, "Illustrations gave me a much easier time to follow along." Also, Student 8 said, "The diagrams of the Base-10 squares helped my understanding. This video's concepts were new to me, and the information was easy to understand and thorough." Furthermore, Student 4 explained that visuals contributed to the explanation of the mathematical concepts by commenting, "Good visuals and clear instructions, contributed to my knowledge of adding/subtracting decimals." These findings confirmed prior research reporting that explanatory visuals are useful features that improve the quality of the instructional videos (Mayer, 2008; Kay, 2014).

Another valued video characteristic was an effective explanation summarizing the most important concepts in the video. In a prior study, teachers believed that lesson closure was an important part of instructional design as determined by a statistically significant difference in video preferences between videos with lesson closure and those without closure (Bloomquist, 2010). Hence, the videos created for this thesis contained a brief summary of the key points presented in the video; except for the Internet-Accessed format video. The majority of students (11 out of 12) in this thesis agreed or strongly agreed that a summary recap at the end of the video helped them retain what they learned (item 2m). Students perceived the summary recap as beneficial to learning, because it highlighted the most important concepts discussed in the video and helped them retain the key concepts. Although students valued this component, there was no statistically significant difference between the videos with a summary component and those without; possibly because there were many aspects that influenced student perceptions of instructional videos. Lesson summaries were absent from Kay's (2014) framework, yet, based on the findings in this thesis, appear to be an important aspect of instructional design and should be included in videos developed for the flipped classroom model.

To summarize, effective explanations were critical to the quality of an instructional videos. Findings from Phase II of this thesis found that, when students were asked to comment on beneficial features of each video, the majority of student responses were related to the effective explanations component of the video. Therefore, students perceived the effective explanations as a key indicator of a quality video that promotes learning and engagement. Additionally, Phase I findings determined that PPT with Narration-1 format was the most engaging video and significantly more engaging compared to almost every other format. The idea that effective explanations is key to the quality of the video is further supported by the fact that one of the main differences between PPT with Narration-1 and PPT with Narration-2, was the accuracy and clarity of explanations in the video. This finding is aligned with the hypothesis, which predicted that students' perceptions of video characteristics rooted in accurate and clearly articulated pedagogy would be higher than videos with a shortfall in pedagogical insight.

Minimizing cognitive load. Learning can be unnecessarily difficult if the extraneous load is high (Chinnappan & Chandler, 2010; Sweller, 1994; Wong et al., 2011). Altering how information is presented can minimize the extraneous load (Chinnappan & Chandler, 2010; Sweller, 1994; Wong et al., 2011). Pedagogical practices such as highlighting (or signalling), organizing the layout, enhancing readability, and notetaking of key information can reduce the extraneous load (Kay, 2014), allowing more working memory to process the inherent difficulty of the concept (Brame, 2015). Videos developed for this study did not always use the pedagogical practices listed above for the purpose of exposing students to both good and not so good videos. As such, student responses documented dissatisfaction with the layout and written text that appeared on the Explain Everything video format. Student 8 commented, "It was kind of hard to read the written text." Furthermore, the majority of students (eight out of 12) strongly agreed or agreed video creators should avoid handwriting, because it was too messy (item 2i). However, the majority of students (seven out of 12) strongly agreed or agreed that handwriting on the video is just as good as typed text or numbers (item 2d). These mixed results may have been influenced by the absence of writing samples in the videos given that all the videos except for the Explain Everything video had typed text. It is possible that students were surmising when responding to the item 2d given that if handwritten text was clearly presented, it can be as effective as typed text.

Also, students indicated that a well-organized layout influenced the perceived usefulness of the video. Student responses suggested the layout of the Explain Everything format increased the cognitive load of the video. Student 6 commented, “I felt this video was a bit sloppy and boring.” and Student 4 noted, “Presentation was not very concise. A bit messy.” However, regarding the layout of the PPT with Narration1 format, Student 3 commented, “The entire format of this video was my favorite out of all the videos. The structure helped me to learn.” Student responses indicated that they preferred the structure and layout of the PPT with Narration1 format compared and the Explain Everything format was the least preferred. Once again, it is important to acknowledge that the platform in which the video was created was not the factor influencing student perceptions but rather the design quality of the video. Saying that, some platforms may be better suited to manipulating figures and less time consuming to create. In the case of this thesis, the PPT with Narration1 was the preferred instructional video based on the design quality of the video, which encompasses most features in Kay’s (2014) framework including minimizing the extraneous load.

Presenting information simultaneously through both audio and visual channels has been shown to enhance learning and reduce the cognitive load (Brame, 2015; Mayer, 2008). Conversely, overloading an audio or visual channel can impede learning (Brame, 2015). For example, Mayer’s (2008) experiments confirmed that students performed better on a transfer test when information was presented with animation and narration compared to when information was presented with animation, narration, and on-screen text. Students commented that animations were helpful features of instructional videos when they were used to move objects, visually connect two ideas, or cue the viewer’s attention. Student 7 commented "I liked seeing the pieces of the fractions and the ability of the instructor to move the pieces around." Also, Student 8 described, "Dragging the pictures to match pictures [of fractions] and matching the numbers and vice versa" was a helpful characteristic. Responses suggested that instructional videos that utilized technology to manipulate figures and diagrams are more effective than static images, which explains why PPT with Narration1 was the most favoured video and PPT with Narration2 was also noted for the animation, text, and narration (albeit, not as clear as the first PPT video).

It was hypothesized that the video capture format may have a high cognitive load due to the unnecessary visual of the teacher. Unfortunately, Phase II findings were inconclusive regarding student perceptions of the video capture format given that four students indicated that they did not watch this video, and the students who did watch the video were split between enjoying the format and not liking the video at all. On one hand, three students responded positively to the visual teacher-presence included in the video capture format. Student 3 noted, "I enjoyed the switch up between the illustrations and a teacher and still able to pause." Conversely, four out of 12 students rated the video capture format a 2 or a 1 on a 5-point scale, where a score of 1 was the poorest rating. Although more research is needed in this area, if cognitive load theory is considered in this context, the visual of the teacher does not add any valuable information that supports the learner in acquiring mathematics. If the visual of the teacher is not necessary, it could be considered a distraction and be excluded from instructional videos.

Engagement. Indicators of the engagement component included video length, appropriate pacing, engaging voice, no distractions in the video and opportunities for students to practice. One of the reasons to provide opportunities for students to practice is to segment the video. Research has found that video segmentation aids in reducing the perceived learning difficulty and required less mental effort (Moreno, 2007) and improved knowledge retention (Ibrahim, 2012). Not only does video segmentation aid in perceived learning and actual learning performance, it also promotes student engagement. In support of this finding, students reported higher levels of engagement with videos that included practice problems and lower levels of engagement with videos that did not include practice problems. In the Screen Capture of an App video that did not contain student practice problems, students commented that the video was boring and had no interaction. Student 1 captured this idea, when he described the Screen Capture of an App format "I felt this video was incredibly slow, watching someone else do several fraction questions dragged on. I would have preferred doing them myself." Student responses strongly indicated the need for instructional mathematics videos to include opportunities for students to practice. The majority (10 out of 12) of students strongly agreed or agreed that effective instructional videos used to teach math must include practice problems for the viewer (item 4e). Furthermore, almost all students (11 out of 12) strongly agreed or agreed that being verbally instructed to pause the video and try an example was a helpful feature (item 2c). In sum, it is highly recommend that instructional mathematics videos provide opportunities for students to practice so that students will perceive the video as useful.

Another video characteristic that students perceived as helpful was the weeding of unnecessary information that did not support learning (Ibrahim et al., 2012). Unnecessary material, such as information or effects that are included for entertainment value, can distract the learner thereby increase the extraneous load (Ibrahim et al., 2012). The majority of participants (seven out of 12) agreed or strongly agreed that fancy features (cartoon animations, music, etc.) were irrelevant as long as a video taught the mathematics well. In contrast, 50% of students (six out of 12) agreed or strongly agreed that instructional videos with humour, such as gifs or pop references, were engaging. This finding contradicts Ibrahim et al.'s (2012) finding who reported that weeding reduced the perceived difficulty of learning. This discrepancy may be attributed to the amount of weeding in an instructional video where a little bit of humor or other unnecessary information that is used to engage students may be beneficial whereas too much unnecessary information may be detrimental to learning. For example, in Ibrahim et al.'s (2012) study, three minutes of weeding was eliminated compared to this thesis where weeding in the form of humor was only utilized for a few seconds. Given the mixed feedback from students regarding animations and other more technical aspects of instructional videos, more research is needed to determine how much weeding is acceptable and where the cut off limit is.

Summary. The findings from this study confirmed several indicators of effective videos in Kay's (2014) proposed framework such as opportunities to practice, a well-organized framework, clear handwritten text, and the importance of effective explanations supported by visuals. Findings from this study also identified several characteristics that should be included in instructional videos. They are:

- Demonstration and practice problems should be aligned with in-class activities and course expectations.

- Effective explanations should be grounded in pedagogy to enhance student engagement
- Dynamic visuals are more engaging and helpful than static images.
- Minimizing the use of entertaining features such as cartoons, music, and humorous excerpts maximize student engagement.
- Concluding each video with a brief summary of key concepts supports student learning.

Upon reflection of Kay's (2014) framework and the additional video characteristics offered above, it is evident that many video characteristics are rooted in pedagogy and instructional design. At the same time, technology needs to be maximized to create dynamic models of mathematical concepts. To create instructional videos that engage students, teachers require pedagogical content knowledge, technological content knowledge, and technological pedagogical knowledge to develop quality instructional videos.

Research Question 3: What are teachers' challenges and reflections in creating instructional videos?

The third question guiding this study pertained to teacher experiences in creating an effective instructional video. The purpose of this research question was to create guidelines that would inform educators who are considering creating instructional videos for the flipped classroom. Previous research recommended that teachers create their own instructional videos for the flipped classroom rather than using videos accessed online (Guo et al., 2014; Moore et al., 2014). Given this recommendation, educators need to be knowledgeable about approaching this task so that the effort put forward produces a quality instructional tool. A reflection survey was used to solicit teachers' reflections and experiences with video creation. The survey was comprised of primarily open-ended items with the inclusion of a few close-ended items that were used to prompt teachers in rating their technological skill.

The integration of technology in education is often a complex process for educators (Earle, 2002; Kaleli-Yilmaz, 2015; Mishra & Koehler; 2006; Stoilescu, 2015). First, teachers must be knowledgeable of content, pedagogy, and technology, and, secondly, they must integrate these three components succinctly to produce a quality instructional product. Therefore, the successful integration of technology depends on the knowledge of the teacher and if teachers have insufficient knowledge in one or more of the three components (i.e., content, pedagogical and technological knowledge). In turn, the creation of an instructional video will no doubt be a challenging task for most educators. The integration of technology in education is also a time-consuming process as reported in studies with nursing students (Corbally, 2005) and pre-service teachers (Hechter & Guy, 2010). Therefore, it was also hypothesized that time would be an issue of video development reported by teachers.

Teachers' perceptions of instructional videos as a tool for learning. When prompted to describe their opinions regarding the creation of instructional videos for mathematics, eight out 12 teachers reported that they believed instructional videos were valuable. Teacher 11's response indicated that videos were engaging and can be used as an alternative form of instruction. Teacher 9 also suggested that students can benefit from this form of instruction when they learn at their own pace. Furthermore, two teachers noted that students were not the sole beneficiaries of instructional videos. Teacher 3 indicated that instructional videos would also be a valuable source of information for parents, and Teacher 8 enthusiastically concluded that creating an instructional video was beneficial to her own teaching practice. Teacher 8 commented:

> It was such a beneficial process. I thoroughly enjoyed the project. I was apprehensive at first, but haven't felt so proud of something I have created in a long time. Loved it! Would love to implement it into my practice on a regular basis.

These teacher responses indicated that instructional videos were a valuable resource for teaching and learning. According to a meta-analysis conducted by Kay (2012), no studies have focused on obtaining teacher perceptions on the use of instructional videos, hence, this aspect of the thesis has been a vital contribution to research. Overall, teachers were very positive about creating instructional videos. However, teachers reported that creating the instructional videos were challenging.

Challenging aspects of video creation. Teachers reported that video creation was a challenge due to factors related to time and technology. Given that teachers were assigned the task of video creation as part of a grade course requirement, they reported having applied special consideration to the pedagogy of the explanation used in their video. Half of the teachers (six out 12) reported that recording pedagogically accurate narration was the most time-consuming aspect of video creation. On average, teachers estimated it required 11 hours to record the narration (M = 11.56; SD = 8.56) with as few as 2 hours and as many as 30 hours, which tended to parallel the range of video quality where shorter videos were less professional and longer videos were more engaging. The significant amount of time teachers spent on recording the narration indicated that either teachers struggled with operating the recording technology or with developing the pedagogically accurate narration. Evidence from open-responses can be found to support both arguments. For example, Teacher 2 noted that the most challenging aspect of video creation was "Questioning whether your video was pedagogical [*sic*] sound. The time investment and number of retakes needed." Teacher 2's response suggested that creating a narrative that demonstrated mathematical pedagogy was the most-challenging aspect of video creation. In comparison, Teacher 3 noted the most challenging aspect was recording the audio. This teacher explained that Movie Maker was not very robust in editing the audio. This finding is aligned with previous research that focused on pre-service teachers' experiences in creating an educational video who also reported that developing the dialog was difficult and required many takes (Hechter & Guy, 2010). Unfortunately Hechter and Guy (2010) did not specifically emphasize the pedagogy of the narration was the difficulty, which was essential to produce a quality video (Kay, 2014). Therefore, the task of recording audio narration is inherently difficult coupled with the development of pedagogically accurate narration compounds the difficulty of this aspect of video production.

Given that this part of video production required the most time, teacher responses advised the use of a script to aid in the delivery. Teacher 6 and Teacher 8 emphasized the importance of writing a script before recording a video. Teacher 6 commented, "Prepare a script to aid in your delivery. This helps immensely." Also, Teacher 8 described the difficulty of the recording process and advised:

> Create your slides. Write a script of what you would like to say. Practice, practice, practice. It will take many takes. When recording yourself, be sure to pause and not talk too much. Your voice should match the animations on the screen.

Teacher responses suggested that a script can be an effective strategy to aid in recording the video narration. Also, teachers should consider selecting software that allows for precise splicing of audio segments so that long pauses, or segments where the audio and animations do not coincide, can easily be removed. For example, Teacher 3 suggested that Movie Maker was not robust in this area. In my experience in creating videos for this study, Camtasia offered the best capabilities in editing the audio compared to Explain Everything and iMovie. Similarly, seven out of 12 teachers used also Camtasia in the production of their video. In sum, careful planning and selecting the appropriate software can enhance the video production and reduce the time involved.

Recalling the Technological Pedagogical Content Knowledge (TPACK) framework, teachers must have pedagogical content knowledge to integrate technology and teaching effectively (Mishra & Koehler, 2006; Stoilescu, 2015). This theory holds true in the case of creating quality instructional videos for the flipped classroom, especially for recording pedagogically accurate narration. Teacher responses indicated that one of the most challenging aspects of video creation was recording pedagogically accurate narration. Teachers reported two strategies for creating quality instructional videos. First, teachers proposed that thorough planning, such as developing a script or storyboard in the pre-production stage, helped to create a better video. Second, teachers also indicated that collaboration was very helpful in creating higher quality videos. Five of 12 teachers reported collaboration was crucial for creating a quality instructional video.

Teacher 2 explained, “It is valuable to create videos for your students, but they should be of high quality. You should seek help from others that are more skilled in other areas. Collaboration is very helpful in creating videos.” Also, Teacher 9 noted that asking for colleague feedback was very helpful during the video preparation. Teacher 9 explained, “It’s helpful to have someone else look at it from a different perception.” Teachers mentioned collaborating with experts as well as colleagues and students, indicating that creating an instructional video provided them with the opportunity to obtain feedback on their teaching.

Considering that teachers who participated in this study were experienced teachers who struggled to create pedagogically accurate narration indicates that pedagogical content knowledge is critical to the development of quality instructional videos. Furthermore, considering that students perceived the effective explanations component as a key indicator of a quality video, pedagogical content knowledge should be more heavily weighted in terms of necessary knowledge needed prior to developing an instructional video. Thus, teachers who have a greater understanding of mathematical pedagogy will be more capable of creating a higher quality instructional video. Furthermore, teachers who are not as advanced in mathematical pedagogy, will experience a greater challenge in creating quality instructional videos and, therefore, would benefit from collaborative opportunities to improve their pedagogical knowledge.

Another challenging aspect of video production was the selection and operation of technology. Half of the teachers (six out of 12) reported that learning and using the technology was the greatest challenge. Teacher 2 reported the most challenging aspect was “Exploring the new technology and trying to make it do what I wanted it to.” Also, Teacher 9 described the numerous new technologies that she needed to learn to produce her video. Teacher 9 commented, “For me, the most challenging aspect is the technology, such as how to create slides in Camtasia, add special effects, record voice-over, share and upload the video to YouTube.”

Instructional videos sometimes required teachers to learn multiple new technologies, which created a greater need for technological content knowledge (TCK) prior to developing an instructional video. No single mathematical technology is best suited for all mathematical content, a point which requires teachers to be aware of multiple mathematical software to deliver a range of mathematics content. For example, in a typical middle school mathematics curriculum, teachers may want to find software or applications for measurement, integers, linear relations, algebra, and trigonometry. Within each topic, there are likely multiple options in terms of software or applications to choose from, further compounding the decision making process. Given the wide selection of technology, teachers will likely need to invest some time to explore what technology is available.

Half of teachers (six out of 12) indicated that they would use different technology to create their next instructional video. Teacher 3, 2, and 11 described the struggle to find one technology that offered all the features and capabilities that are desired. Teacher 2 wanted to use software with better animation effects than PowerPoint and wanted to use software like Explain Everything that allowed virtual ink annotation. Teacher 11 also noted the challenge in choosing between software that offered strong visual features and software that supported graphing calculators. Teacher 4, who used PowToon, an animated presentation builder, spent two days learning the new software. When prompted with the question, “What would you do differently?” she commented that she would create her next instructional video using the video capture format. The video capture format required a low-level of technology and, therefore, considerably less time to produce this type of video.

Synthesis from comments provided by practicing teachers suggested that technological content knowledge is required for teachers to integrate teaching and technology. Thus, if teachers are unfamiliar with software and other technologies that can be used to deliver the content, teachers will struggle and spend more time in developing this area of knowledge prior to developing an instructional video. On the other hand, teachers may choose an easier method, utilizing technology with which are already familiar to avoid wasting time as was noted by Teacher 5. However, as discussed earlier in this chapter, the low-technology format (i.e. video capture format) was not necessarily an effective format but was time efficient if teachers wanted to experiment with little time investment in the flipped classroom. The challenge is that the video capture format does not really utilize technological content knowledge to improve instruction but only utilizes technology to deliver the same kind of instruction digitally. Unless teachers have technological content knowledge (i.e. knowledge of mathematical software), it would be difficult to apply technological pedagogical knowledge, such as signaling, segmenting, and weeding, which has been established as effective practices in multimedia learning. Therefore, it is necessary for teachers to develop technological content knowledge by familiarizing themselves with mathematical software, so that the benefits of integrating technology are fully actualized, even though it may require a considerable amount of time.

According to teacher responses, it is clear that technological content knowledge (i.e. knowledge of mathematical software) was a significant factor that shaped their experiences creating an instructional video. For some teachers, learning how to use the technology was a challenge. For other teachers, the limited capabilities of the software they chose impeded their ability to produce the video they envisioned. Therefore, teachers who are considering creating instructional videos will want to take the time to identify software that can accomplish how they wish to produce the video.

As hypothesized, elements of content, technology, and pedagogy shaped teacher experiences in creating an instructional video. Teachers identified both creating pedagogically accurate narration and using technology presented challenges to produce a quality instructional video. One common theme with these challenges was the element of time. Research that has investigated the integration of technology in classrooms has reported that teachers were concerned about the amount of time required to integrate technology successfully (Bauer & Kenton, 2005; Hur, Shannon & Wolf, 2016). The results of this study confirmed findings from previous research that reported creating an instructional video was a time-consuming task (Corbally, 2005; Hechter & Guy, 2010; Thomson et al., 2014). Teachers reported that overall they estimated it took an average of 40 hours to create their video ($M = 40.33$; $SD = 21.19$), which ended up to be about 10 minutes in length. At that rate, creating an instructional video for every lesson would be impossible. As one teacher pointed out, “A teacher should not think they need to create a video for everything since it is so time consuming.” Although the time required to create an effective instructional video was significant, teachers in this study considered it a worthwhile process. Two teachers did suggest the use of collaboration as a strategy to complete a bank of course videos. Also, as discussed previously, teachers' responses indicated that they valued instructional videos and considered them to be an effective instructional tool. However, they suggested that creating a volume of instructional videos to teach an entire course would be an immensely time-consuming task, one that could not be quickly implemented in the context of a flipped classroom.

Conclusions and Recommendations

The purpose of this study was to explore video design format and characteristics of effective instructional videos. Given that it is the pedagogy, not the technology that teaches students (Earle, 2002; Okojie et al., 2006; Osborne, 2014; Snyder, 2013), it was hypothesized that students would perceive video characteristics and video design formats that were rooted in accurate and well-communicated pedagogy, beneficial to their learning. Considering that teachers will be the active players in selecting or developing instructional videos in the flipped classroom model, their perceptions on the use and development of instructional videos were also collected. Recalling the TPACK framework, teachers must have knowledge of pedagogy, content, and technology to integrate technology into learning successfully. Therefore, it was hypothesized that teachers might experience challenges in learning different technologies to enhance pedagogical techniques in their videos (Stoilescu, 2015) as well as be challenged with the time commitment involved in creating videos (Corbally, 2005; Hechter & Guy, 2010; Thomson et al., 2014). Both hypotheses were found to be true, and conclusions were made based on the findings from all three phrases.

Results from this study indicate that teachers cannot rely on the technology to deliver instruction effectively and engage students. The use of technology alone was not enough to engage students. Student engagement was significantly influenced by the design of the instructional video. Furthermore, students identified pedagogical characteristics as useful features in an instructional video. Based on the findings from this study, a pedagogical framework for effective mathematics videos recommends:

- a selection of appropriate problems that range from basic to more complex problems;
- appropriate problems that present content that is aligned with in-class activities and course expectations;
- step-by-step explanations that are grounded in pedagogy supported with dynamic visuals ;
- well-organized layouts that present only necessary information in smaller units
- clear handwriting or typed text;
- signal or highlight important information to minimize the cognitive load;
- create opportunities for students to practice; and
- a recap or summary of important points learned throughout the video.

In conclusion, video design and characteristics that integrate pedagogical practices were more engaging and useful features of instructional videos.

For teachers beginning to create instructional videos, pedagogical content knowledge, technological pedagogical knowledge, and technological content knowledge were critical to producing quality instructional videos. Teachers suggested video development should begin by watching other instructional videos on similar topics followed by collaboration with colleagues regarding the ideal pedagogy. Creating pedagogically accurate narration and working with technology was the most challenging aspect of video creation for teachers. To overcome these challenges, teachers suggested thorough pre-production planning and collaboration. Teachers also reported that the task of creating an instructional video acted as a vehicle to discuss, demonstrate, and model effective mathematical pedagogy. For this reason, teachers' experiences creating instructional videos were perceived as valuable. Such a learning experience can act as a tool for ongoing professional development. Even though developing an instructional video was time-consuming, teachers believed quality instructional videos were valuable resources since the instructional videos were an opportunity to engage students.

Additional research is needed to determine if the visual of a teacher is beneficial to learning in an instructional video. Two teachers from this study commented that they preferred to film themselves in video and produce the video in front of the whiteboard. It is unclear why they preferred this style of video production. Previous studies suggested that a teacher presence increased student engagement (Moore et al., 2014); however, this was not the case in this study. A possible reason why teachers may prefer recording the video in the classroom would be because it involved less complex integration of technology and time. However, since the visual of the teacher does not convey additional information to the student that supports the learning goal, it may be considered a distraction (Rossi, 2015). Nevertheless, more research is needed in this style of instructional video development.

Another video characteristic that could be researched further is the use of pop references or humor in instructional videos. Prior research suggested that any information or material that did not support the learning goal should be removed (Kay, 2014; Rossi, 2015). However, 10 out of 12 students in this study disagreed or strongly disagreed that entertaining features were needed to keep them interested in the video. On the other hand, half of the students agreed or strongly agreed instructional videos that include some humor were more engaging. Findings from this aspect of this thesis were inconclusive and more research is needed in this area.

Implications for Practice

Results from this study and others agree that students view instructional videos as valuable learning tools (Kay, 2012; Lloyd & Robertson, 2012; Moore & Smith, 2012; Rackaway, 2012; Thomson et al., 2014). Furthermore, findings from this study were consistent with that of other research that found students believed they learned more from instructional videos as compared to traditional lectures (Day & Foley, 2006; Kay, 2014; Love, 2014; Sahin et al., 2014). Therefore, instructional videos can be an effective form of instructional delivery and can alter the way teachers use class time. Creating instructional videos for students to view asynchronously provides the teacher and the student with an opportunity to change the one-size-fits-all classroom.

Before the creation and widespread use of digital technologies, the opportunity to provide instruction beyond the classroom was very limited. Current technology has given educators the opportunity to provide students with increased accessibility to educational resources. Increased accessibility to educational resources, such as instructional videos, can make education asynchronous, which supports the current theories of learning acknowledging that not everyone learns in the same way or at the same rate. Since it is no longer necessary to deliver teacher-directed lessons in the classroom, classroom time can be devoted to many other activities, such as higher-order skills-based activities, activities that involve peer interaction, or effective one-on-one or small group instruction.

Regardless of whether a teacher decides to pursue a flipped classroom model or not, instructional videos can provide opportunities to change the way teachers use class time.

This study also has implications for professional development and teacher education. The creation of instructional videos is not only useful to students but can also act as a vehicle for professional development, particularly for an experienced teacher. Firstly, while the teacher is developing the video, they must consider the pedagogical approach that will work best. This provides the teacher with an opportunity to consult colleagues or other pedagogical experts to explore alternative ways to teach the content. Second, by creating an instructional video, teachers are creating samples of their work that others can view asynchronously. The opportunity to watch another teacher's lesson rarely presents itself but capturing the lesson in a digital format allows the teacher to share their approach and seek advice to improve their practice.

Strengths and Limitations

A strength of this thesis was the utilization of two sources of data with two sets of participants utilising open and closed-responses. Obtaining data from students who viewed instructional videos and teachers who created instructional videos provided an opportunity to contrast different experiences and nuances with the use and development of instructional videos.

One limitation of this study was the small number of participants from both sources of data. Perceptions of instructional videos were collected from 12 pre-service teachers (students) and 12 MEd students (teachers). Although a larger sample is more reliable, the pre-service teachers in this study represented a wide range of mathematics skills given that they enrolled in the Mathematics for Teachers course as a pre-requisite since they did not have the mathematics background. Likewise, the teachers in this study also represented a wide range of expertise from five years of experience up to 15 year and grades in which they taught also ranged from Kindergarten to Grade 12.

While the results were reliable, student perceptions reported in this thesis are representative of post-secondary students and cannot be necessarily extended to school-aged children. Pre-service teachers were purposefully sought to participate in this thesis since it was probable that they would complete their homework (i.e. watch the videos). Further research is needed to determine whether younger students in the public education system would respond similarly to the use of instructional videos. In particular the question, at what age are instructional videos an asset to learning?

Lastly, the duration of this thesis was another limitation. As previously noted, the study took place over a compressed 5-week period with lessons occurring twice a week. Although 10 three hour lessons are typical of BEd programs, it is not reflective of a three-month term in public schools or post-secondary institutions. Hence, further research should consider the experimentation with instructional videos over a full course term. This is not to say that each lesson requires an instructional video but some pattern of use (e.g., one or two videos per week) would explore whether students' perceptions towards instructional videos was related to a novelty effect.

REFERENCES

Almalki, S. (2016). Integrating quantitative and qualitative data in mixed methods research – Challenges and benefits. *Journal of Education and Learning, 5*(3), 288–296. doi:10.5539/jel.v5n3p288

Ani, K. K. (2013). Khan Academy: The hype and the reality. *Education Digest, 78*(6), 23–25.

Bauer, J., & Kenton, J. (2005). Toward technology integration in the schools: Why it isn't happening. *Journal of Technology and Teacher Education, 13*(4), 519–546.

Bishop, J. L., & Verleger, M. A. (2013). *The flipped classroom: A survey of the research*. Retrieved from http://www.studiesuccesho.nl/wpcontent/uploads/2014/04/flipped-classroom-artikel.pdf

Bloomquist, T. P. (2010). *Effectiveness of closure in lesson design: A quasi-experimental investigation* (Doctoral dissertation). George Fox University, Newberb, Or. Abstract retrieved from http://gradworks.umi.com/34/46/3446498.html

Brame, C. J. (2015). *Effective educational videos*. Retrieved from http://cft.vanderbilt.edu/guides-sub-pages/effective-educational-videos/

Burget, M., Pedaste, M., Uger, K., & Lõhmus, E. (2014). *How can videos help achieve educational objectives?* Retrieved from https://library.iated.org/view/BURGET2014HOW

Chen, Y., Wang, Y., Kinshuk, & Chen, N. S. (2014). Is FLIP enough? Or should we use the FLIPPED model instead? *Computers and Education, 79,* 16–27.

Chinnappan, M., & Chandler, P. A. (2010). Managing cognitive load in the mathematics classroom. A*ustralian Mathematics Teacher, 66* (1), 5–11.

Collins, A., & Halverson, R. (2010). The second educational revolution: Rethinking education in the age of technology. *Journal of Computer Assisted Learning, 26*(1), 18–27. doi:10.1111/j.1365-2729.2009.00339.x

Corbally, M. A. (2005). Considering video production? Lessons learned from the production of a blood pressure measurement video. *Nurse Education in Practice, 5,* 375–379. doi:10.1016/j.nepr.2005.04.003

Creswell, J. W. (2012). *Educational research: Planning, conducting and evaluating quantitative and qualitative research* (4th ed., International ed.). Boston, MA: Pearson.

Day, J. A., & Foley, J. D. (2006). Evaluating a web lecture intervention in a human–computer interaction course. *IEEE Transactions on Education*, *49*(4), 420–431.

DeSantis , J., van Curen, R., Putsch, J., & Metzger, J. (2015). Do students learn more from a flip? An exploration of the efficacy of flipped and traditional lessons. *Journal of Interactive Learning Research, 26*(1), 39–63.

Douch, A. (2014). *The best screencasting software for teachers*. Retrieved from https://andrewdouch.wordpress.com/2014/02/13/the-best-screencasting-software-for-teachers/

Earle, R. S. (2002). The integration of instructional technology into public education: Promises and challenges. *Educational Technology Magazine, 42*(1), 5–13. Retrieved from https://pdfs.semanticscholar.org/a9a0/a4f93c0822701e6ffdb8b8606bf1bbcd1bb8.pdf

Explain Everything. (n.d.). Retrieved from https://explaineverything.com/

Fullan, M. (2013). The new pedagogy: Students and teachers as learning partners. In Butler-Kisbar L. (Ed.) *LEARNing Landscapes, 6*(2), 23–30.

Fulton, K. (2012). Upside down and inside out: Flip your classroom to improve student learning. *Learning and Leading with Technology,* (June/July 2012), 13–17.

Gilboy, M.B, Heinerichs, S., & Pazzagalia, G. (2014). Enhancing student engagement using the flipped classroom. *Journal of Nutrition Education and Behaviour, 47,* 109-114.

Goldman, M. (2008). Why is multiple testing a problem? Retrieved from http://www.stat.berkeley.edu/~mgoldman/Section0402.pdf

Groff, J. (2013). Technology-Rich innovative learning environments. Retrieved from http://www.oecd.org/edu/ceri/Technology-Rich%20Innovative%20Learning%20Environments%20by%20Jennifer%20Groff.pdf

Guerrero, S., Beal, M., Lamb, C., Sonderegger , D., & Baumgartel, D. (2015). Flipping undergraduate finite mathematics: Findings and implications. *PRIMUS, 25*(9-10), 814–832. doi: 10.1080/10511970.2015.1046003

Guo, P. J., Kim, J., & Rubin, R. (2014, March). How video production affects student engagement: An empirical study of MOOC videos. *Proceedings of the first ACM conference of learning at scale conference,* 41–50. http://dx.doi.org/10.1145/2556325.2566239

Hechter, R. P., & Guy, M. D. (2010) Promoting creative thinking and expression of science concepts among elementary teacher candidates through science content movie creation and showcasing. *Contemporary Issues in Technology and Teacher Education, 10*(4), 411–431.

Herreid, C.F., & Schiller, N. A. (2013). Case studies and the flipped classroom. *The Journal of College Science Teaching, 42*(5), 62–66.

Holm, S. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics, 6*(2), 65–70.

Hur, J. W., Shannon, D., & Wolf, S. (2016). An investigation of relationships between internal and external factors affecting technology integration in classrooms. *Journal of Digital Learning in Teacher Education, 32*(3), 105-114. doi: 10.1080/21532974.2016.1169959

Ibrahim, M., Antonenko, P. D., Greenwood, C. M., & Wheeler, D. (2012). Effects of segmenting, signalling, and weeding on learning from educational video. *Learning, Media and Technology, 37*(3), 220-235. doi: 10.1080/17439884.2011.585993

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed Methods Research: A research paradigm whose time has come. *Educational Researcher, 33*(7), 14–26.

Kaleli-Yilmaz, G. (2015). The views of mathematics teachers on the factors affecting the integration of technology in mathematics courses. *Australian Journal of Teacher Education, 40*(8), 132–148. http://dx.doi.org/10.14221/ajte.2015v40n8.8

Kay, R. H. (2012). Exploring the use of video podcasts in education: A comprehensive review of the literature. *Computers in Human Behavior, 28,* 820–831.

doi:10.1016/j.chb.2012.01.011

Kay, R. H. (2014). Developing a framework for creating effective instructional video podcasts. *iJET, 9*(1), 22–30.

Kennedy, E., Beaudrie, B., Ernst, D.C., & St. Laurent, R. (2015). Inverted pedagogy in second semester calculus course. *Problems, Resources, and Issues in Mathematics Undergraduate Studies, 25(*9-10), 892-906. doi:10.1080/10511970.2015.1031301

Khan, S. (2011). *Let's use video to reinvent education.* [TED Talk]. Available from https://www.ted.com/talks/salman_khan_let_s_use_video_to_reinvent_education

Kohl, H. (1994). I won't learn from you, New York: The New Press.

Kim, M. K., Kim, S. M., Khera, O., & Getman, J. (2014). The experience of three flipped classrooms in an urban university: An exploration of the design principles. *Internet and Higher Education, 22,* 37–50.

Little, C. (2015). The flipped classroom in further education: Literature review and case study. *Research in Post-Compulsory Educatio*n, 20(3), 265–279, doi:10.1080/13596748.2015.1063260

Lloyd, S. A., & Robertson, C. L. (2012). Screencast tutorials enhance student learning of statistics. *Journal of Psychology, 39*(1), 67-71.

Long, T., Logan, J., & Waugh, M. (2016). Students' perceptions of the value of using videos as a pre-class learning experience in the flipped classroom. *TechTrends, 60*, 245–252. doi: 10.1007/s11528-016-0045-4

Losby, J. (2012). *CDC Coffee Break: Using Likert Scales in Evaluation Survey Work* [PowerPoint slides]. Retrieved from https://www.cdc.gov/dhdsp/pubs/docs/cb_ february_14_2012.pdf

Love, B., Hodge, A., Grandgenett, N., & Swift, A.W. (2014). Student learning and perceptions in a flipped linear algebra class. *International Journal in Mathematical Education in Science and Technology, 45*(3), 317–324.

Mason, G.S., Schuman, T.R., & Cook, K.E. (2013). Comparing the Effectiveness of an Inverted Classroom to a Traditional Classroom in an Upper-Division Engineering Course. *IEEE Transaction on Education, 54*(4), 430–435.

Mayer, R. E., & Johnson, C. L. (2008). Revising the redundancy principle in multimedia learning. *Journal of Educational Psychology, 100*(2), 380–386. http://dx.doi.org/10.1037/0022-0663.100.2.380

McCue, T. J. (2014, August 27). Online Learning Industry Poised for $107 Billion In 2015. Retrieved from http://www.forbes.com/sites/tjmccue/2014/08/27/online-learning-industry-poised-for-107-billion-in-2015/#63cae06d66bc

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*(6), 1017–1054.

Moore, A. J., Gillett, M. R., & Steele, M. D. (2014). Fostering student engagement with a flip. *The Mathematics Teacher, 107*(6), 420–425.

Moore, W. A., & Smith, A. R. (2012). Effects of video podcasting on psychomotor and cognitive performance, attitudes and study behaviour of student physical therapists. *Innovations in Education and Teaching International, 49*(4), 401–414. http://dx.doi.org/10.1080/14703297.2012.728876

Moravec, M., Williams, A., Aguilar-Roca, N. & O'Dowd, D.A. (2010). Learn before lecture: A strategy that improves learning outcomes in a large introductory biology course. *Life Sciences Education, 9,* 473–481.

Moreno, R. (2007). Optimising learning from animations by minimizing cognitive load: Cognitive and affective consequences of signalling and segmentation methods. *Applied Cognitive Psychology, 21*, 765 - 781. doi:10.1002/acp.1348

Morgan, H. (2014). Focus on technology: Flip your classroom to increase academic achievement. *Childhood Education, 90*(3), 239–241, doi: 10.1080/00094056.2014.912076

Munshi, J. (2014) A method for constructing Likert scales. *Social Science Research Network.* http://dx.doi.org/10.2139/ssrn.2419366

National Council of Teaching Mathematics (2007). What instructional strategies are effective in helping students with difficulties in mathematics? Retrieved from http://www.nctm.org/uploadedFiles/Research_and_Advocacy/research_brief_and_clips/Student_with_Difficulties_Clip.pdf

Nemo, J. (2016, Mar 8). The $107 Billion Industry That Nobody's Talking About. Retrieved from http://www.inc.com/john-nemo/the-107-billion-industry-that-nobodys-talking-about.html

Organisation for Economic Co-operation and Development (OECD). (2010). Are the new millennium learners making the grade? Technology use and educational performance in PISA 2006. Paris, France: OECD. Retrieved from http://eskills4jobs.ec.europa.eu/c/document_library/get_file?p_l_id=10713&folderId=10545&name=DLFE-2306.pdf

Organisation for Economic Co-operation and Development (OECD). (2011). Literacy for life: Further results from the adult literacy and life skills survey. Paris, France: OECD. Retrieved from http://www.statcan.gc.ca/pub/89-604-x/89-604-x2011001-eng.pdf

Organisation for Economic Co-operation and Development (OECD). (2013). Technical report of the suvey of adult skills (PIAAC). Paris, France: OECD. Retrieved from http://www.oecd.org/skills/piaac/_Technical%20Report_17OCT13.pdf

Okojie, M. C., Olinzock, A. A., & Okojie-Boulder, T. C. (2006) The pedagogy of technology integration. *Journal of Technology Studies.* doi:10.21061/jots.v32i2.a.1

Osborne, R. (2014). *An ecological approach to educational technology: Affordance as a design tool for aligning pedagogy* (Doctoral dissertation, University of Exeter). Retrieved from https://ore.exeter.ac.uk/repository/handle/10871/16637

Pallant, J. (2010). *SPSS Survival Manual*. Maiden head, Philadelphia: Open University Press.

Papert, S., & Markowsky, G. (2013). The state of learning: A preview. *Learning Landscapes, 6*(2), 31–35.

Phet Interactive Simulations. (2017). Retrieved from https://phet.colorado.edu

Pythagorean Theorem. (n.d.). Retrieved from https://tapintoteenminds.com/pythagorean-theorem-part1/

Rackaway, C. (2012). Video killed the textbook star?: Use of multimedia supplements to enhance student learning. *Journal of Political Science Education, 8,* 189-200. doi: 10.1080/15512169.2012.667684

Raths, D. (2013) Nine video tips for a better flipped classroom. *T.H.E Journal, 40*(11), 23–18.

Roach, T. (2014). Student Perceptions toward flipped learning: New methods to increase interaction and active learning in economics. *International Review of Economics Education, 17,* 74-84.

Roppa, S. (2014). Attuning students' attention throughout a lecture. *International Journal of Pharma and Bio Sciences, 5*(1), 396–399.

Rossi, R. D. (2015). Chemical conference on flipped classroom: Improving student engagement in organic chemistry using the inverted classroom model. *The Journal of Chemical Education, 92*, 1577–1579.

Roth, J. (2016, April 13). 5 Amazing eLearning trends of 2016. Retrieved form https://elearningindustry.com/5-amazing-elearning-trends-2016

Rimm-Kaufman, S. E. (2010). Student engagement in mathematics survey (SEMS). Retrieved from http://www.socialdevelopmentlab.org/wp-content/uploads/2015/03/SEMS_pdf.pdf

Sahin, A., Cavazoglu, B., & Zeytuncu, Y. E. (2014). Flipping a college calculus course: A case study. *Educational Technology & Society,18*(3), 142–152.

Schlechty, P. (2002). *Working on the Work.* San Francisco, CA: Jossey-Bass.

Shafer, K. G. (2010). The proof is in the screencast. *Contemporary Issues in Technology and Teacher Education, 10*(4), 383–410.

Snyder, T. (2013). At the evolving intersection of teaching and technology. In Butler-Kisbar L. (Ed.) *LEARNing Landscapes, 6*(2), 37–44.

Staker, H., & Horn, M. (2012). Classify K-12 blended learning. *Innosight institute.* Retrieved from http://files.eric.ed.gov/fulltext/ED535180.pdf

Strayer, J. F. (2012). How learning in an inverted classroom influences cooperation, innovation and task orientation. *Learning Environment Res, 15,* 171–193.

Stoilescu, D. (2015). A critical examination of the technological pedagogical content knowledge framework: Secondary school mathematics teachers integrating technology. *Journal of Educational Computing Research, 52*(4), 514–547.

Stoffa, R., Kush, J. C., Heo, M. (2010). Using the motivated strategies for learning questionnaire and the strategy inventory for language learning in assessing motivation and learning strategies of generation 1.5 Korean immigrant students. *Education Research International 2011,* 1-8,. doi: 10.1155/2011/491276

Strayer, J. F., Hart, J. B., & Bleiler, S. K. (2015). Fostering instructor knowledge of student thinking using the flipped classroom. *PRIMUS, 25*(8), 724–735. doi: 10.1080/10511970.2015.1031306

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*(2), 257–285. doi: 10.1207/s15516709cog1202_4

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction, 4*(1), 295–312.

Sweller, J. (2010). Element interactivity and intrinsic, extraneous and germane cognitive load. *Educational Psychology Review*, *22*, 123–128. doi:10.1007/s10648-010-9128-5

“What is TPACK?” (n.d.). Retrieved from http://www.ttf.edu.au/what-is-tpack/what-is-tpack.html

Tabachnick, B. G., & Fidell, L. S. (2012). Using multivariate statistics. (6th ed.). Boston: Allyn & Bacon.

Thompson, A., Bridgstock, R., & Willems, C. (2014). “Teachers flipping out”: Beyond the online lecture: Maximizing the Educational Potential of Video. *Journal of Learning Design, 7*(3), 67–78.

Wilson, S. G. (2013). The flipped class: A method to address the challenges of an undergraduate statistics course. *Teaching of Psychology, 40*(3), 193–199.

Wong, T. H., Ip, E. J., Lopes, I., & Rajagopalan, V. (2014). Pharmacy students' performance and perceptions in a flipped teaching pilot on cardiac arrhythmias. *American Journal of Pharmaceutical Education, 78*(10), 1-6.

Yong, D., Levy, R., & Lape, N. (2015). Why no difference? A controlled flipped classroom study for an introductory differential equations course. *Problems, Resources, and Issues in Mathematics Undergraduate Studies, 25, (*9-10), 907–921. doi: 10.1080/10511970.2015.1031307

Van de Walle, J., Karp, K. S., Bay-Williams, J. M., McGarvey, L. M., & Folk, S. (2014). *Elementary and middle school mathematics: Teaching developmentally (4th ed.)* Boston: Pearson.

Appendix A

Engagement Survey

1. Indicate whether you watched the video last night (choose one)
   - □ I watched it from beginning to end
   - □ I watched all of the video but I was distracted sometimes
   - □ I watched some of it
   - □ I did not watch it

2. What time did you watch the video? (Indicate the approximate hour in the morning or night) ____

3. Describe the big idea in the video you watched last night? Provide as much detail as you can about the concepts or examples presented in the video.

4. If there is anything else that you would like to comment on about the video you watched last night, please write it below:

5. Place a check mark ✓ in the box indicating how often you did the following while watching the video.

During the video how many times did you ….	More than once	Only once	Never
a. ... check your cell phone?			
b. ... press the pause button			
c. ... rewind the video to review part of the video a second time?			

6. Read each statement and circle the number that fits.

Statement	No, not at all true	A little true	True	Yes, very true
a. While watching the video, I focused as hard as I could to learn the concept (s).	1	2	3	4
b. I discussed the video with at least one of my peers.	1	2	3	4
c. After watching the video, I feel comfortable helping a peer with the content that was presented in the video.	1	2	3	4
d. Watching the video was great way to learn about math.	1	2	3	4
e. I felt bored watching the video.	1	2	3	4
f. The video was just okay.	1	2	3	4
g. I would prefer to learn the math from an instructor.	1	2	3	4
h. I enjoyed thinking about math while I watched the video.	1	2	3	4
i. While watching the video, it was important to me that I understood the math really well.	1	2	3	4
j. I tried to learn as much as I could while watching the video.	1	2	3	4
k. While watching the video, I felt that learning math was interesting.	1	2	3	4
l. While I was watching the video, I liked the feeling of solving problems	1	2	3	4
m. While watching the video, I did a lot of thinking.	1	2	3	4
n. Too much information was presented in the video.	1	2	3	4
o. I would rather work on practice questions than watch a video for homework in math.	1	2	3	4

Appendix B

Overall Feedback Survey

1. A picture of each video is shown below. In the box to the right of the picture identify:
   A. The features of the video that helped you learn the mathematics such as:
      Level of difficulty
      Clarity of narration
      Instructions describing the mathematics
      Opportunities to practice
      Level of interactivity
      Etc.
   B. Your overall preference for each style of video

If you did not watch the video, then indicate "Did not watch"

Video *(a screenshot of each video was provided to remind the student)*	**Identify:** **A. The features of each video that helped you learn the mathematical concepts and** **B. Your overall preference for each style of video.**
a. Using Base 10	
b. Multiplication Strategies	
c. Intro to Fractions	
d. Pythagorean Theorem	
e. Introduction to Decimals	
f. Adding/Subtract Decimals	
g. Divide Decimals	
h. Multiplying Decimals	
i. Introduction to Volume	
j. Volume of Triangular Prism	
k. Slope	

2. The following set of questions explores the extent to which various **aspects** of each video were helpful to your learning of mathematics.

Indicate the extent to which …	**Strongly Disagree**			**Strongly Agree**
a. The recap (or summary) at the end of the video helped me remember what I learned in the video.	1	2	3	4
b. Background music was a nice touch.	1	2	3	4
c. The opportunity to pause and practice the math was helpful.	1	2	3	4
d. Hand-writing on the video is just as good as typed text/numbers.	1	2	3	4
e. Background music was distracting.	1	2	3	4
f. Animation (character moving across the screen or poof of smoke) is entertaining	1	2	3	4
g. An exercise sheet at the end of the video would be just as good as having practice questions within the video.	1	2	3	4
h. Typed text/numbers is neat and easy to read.	1	2	3	4
i. Video creators should avoid handwriting because it is too messy.	1	2	3	4
j. Instructional videos for difficult concepts in mathematics are very helpful.	1	2	3	4
k. Fancy features (animations, music, etc) are irrelevant as long as a video teaches the math well.	1	2	3	4
l. The addition of practice problems to try on my own helped me learn the math.	1	2	3	4
m. The recap (or summary) at the end of the video helped me to retain what I learned in the video.	1	2	3	4

3. The videos used in class were created using four main formats:

a. PowerPoint with narration (intro to base 10, multiplication strategies, Decimals)
b. PowerPoint with narration and background music (Pythagorean Theorem)
c. Screen capture of an app (intro to fractions)
d. Explain Everything App where the creator can add hand-drawn diagrams and labels (intro to volume).
e. Video capture of teacher at whiteboard (slope)

For each video indicate your preference for watching that type of video
5 – This is the best format for a video
1 – This is NOT a good format for making instructional videos
NA – I didn't watch this video
CR – Cannot Remember
NP – No preference

	5	4	3	2	1	Other
a. PowerPoint with Narration						
b. PowerPoint with Narration and Background Music						
c. Screen capture of an App						
d. Explain Everything App						
e. Video capture						

4. Summary. This section surveys your overall perceptions towards using instructional videos.

Effectiveness and Use of Instructional Videos for Teaching Mathematics				
Statement	**No, not at all true**	**A little true**	**Often True**	**Yes, very true**
a. A course with instructional videos is better than a course without videos.	1	2	3	4
b. I prefer to do practice problems for math homework than watch a video.	1	2	3	4
c. I believe that the instructional videos helped me learn more.	1	2	3	4
d. Learning math through an instructional video is an effective way to learn math.	1	2	3	4
e. Effective instructional videos used to teach math must include practice problems for the viewer.	1	2	3	4
f. Effective instructional videos that present more challenging content are more engaging.	1	2	3	4
g. Instructional videos that summarize key ideas at the end are more effective.	1	2	3	4
h. Instructional videos that include some humour, such as gifs or pop references, are more engaging.	1	2	3	4
i. Instructional videos that are short and quick to a point are more effective.	1	2	3	4
j. Instructional videos should be avoided.	1	2	3	4
k. Overall, instructional videos are an effective way to learn math.	1	2	3	4
l. Instructional videos should not be used to learn mathematical concepts.	1	2	3	4
m. If the concepts presented in the video was too easy, I tuned out.	1	2	3	4
n. If the concepts presented in the video was too hard, I tuned out.	1	2	3	4
o. Entertaining features are needed to keep me interested in the video.	1	2	3	4
p. The instructional video prepared me for class.	1	2	3	4

Appendix C

Teacher Reflection Survey

1. What software did you use to create your video?

2. Rate your technological skills
    a. I know microsoft office products but that's about it.
    b. I know microsoft office and feel fairly confident learning new software on my own.
    c. I pretty good on the computer ... a lot of my friends ask me to help them with their tech problems.
    d. I am not an expert but I know computers very well.

3. Rate your video design skills.
    a. Creating instructional videos is new to me
    b. I've dabbled a little bit in the past
    c. I've made an instructional video before but it wasn't very good
    d. I've made an instructional video before and have a good handle on how to make good videos.

2. Overall, how many hours did it take for you to create your video?

3. We would like to know more about how your time was spent creating the video. List the approximate amount of time spent in the different video design stages
    a. planning
    b. making the slides/animations
    c. adding the narration
    d. other

4. a) If you were to create another video, describe what would you do differently?
   b) Describe what would you keep the same?

5. What advice would you give to a practicing teacher if he/she were interested in creating videos for his/her classroom?

6. What was the most challenging aspect of creating your video?

7. You have viewed 11 other videos, how does your video compare to the other videos?
    a. It is one of the top 3 videos.
    b. It is in the middle of the pack.
    c. It is one of the bottom 3.

8. Describe other thoughts or reflections or recommendations about creating videos for mathematics instruction.

Appendix D

Descriptive Statistics Summary

Table D.1

Students' scores for describing the big idea (Engagement Survey Item #3)

Video Design Format	4/4	3/4	2/4	1/4	*M*	*SD*
PPT with Narration	2 (16.7)	4 (33.3)	4 (33.3)	1 (8.3)	2.64	0.924
Screen Capture of App	6 (50.0)	5 (41.7)	1 (8.3)		3.42	0.669
Internet-Accessed	4 (33.3)	2 (16.7)	4 (33.3)	1 (8.3)	2.82	1.079
Video Capture	5 (41.7)	1 (8.3)	2 (16.7)		3.38	0.916
Explain Everything	3 (25.0)	4 (33.3)	4 (33.3)		2.91	0.831

Note: Scores in brackets are measured in percent.

.

Table D.2

Summary of responses to engagement survey among different video design formats (Engagement Survey Item #6)

Item #6	Video Design Formats	Yes, very true	True	A little True	No, not at all true	*M*	*SD*
Q6a While watching the video, I focused as hard as I could to learn the concept (s).	PPT with Narration1	2 (16.7)	3 (25.0)	5 (41.7)	1 (8.3)	2.55	0.934
	Screen Capture of App	1 (8.3)	3 (25.0)	6 (50.0)	2 (16.7)	2.25	0.866
	Internet-Accessed		4 (33.3)	3 (25.0)	4 (33.3)	2.00	0.894
	PPT with Narration2		4 (33.3)	6 (50.0)	2 (16.7)	2.17	0.718
	Video Capture		5 (41.7)	2 (16.7)	2 (16.7)	2.33	0.866
	Explain Everything		3 (25.0)	6 (50.0)	1 (8.3)	2.20	0.632

Q6b I discussed the video with at least one of my peers.	PPT with Narration1	2 (16.7)	2 (16.7)	1 (8.3)	6 (50.0)	2.00	1.265
	Screen Capture of App	2 (16.7)	3 (25.0)	1 (8.3)	6 (50.0)	2.08	1.240
	Internet-Accessed			2 (16.7)	9 (75.0)	1.18	0.405
	PPT with Narration2	2 (16.7)		1 (8.3)	9 (75.0)	1.58	1.165
	Video Capture	2 (16.7)	4 (33.3)		3 (25.0)	2.56	1.236
	Explain Everything		3 (25.0)	2 (16.7)	5 (41.7)	1.80	0.919
Q6c After watching the video, I feel comfortable helping a peer with the content.	PPT with Narration1	3 (25.0)	4 (33.3)	3 (25.0)	1 (8.3)	2.82	0.982
	Screen Capture of App	7 (58.3)	4 (33.3)	1 (8.3)		3.50	0.674
	Internet-Accessed	4 (33.3)	2 (16.7)	2 (16.7)	3 (25.0)	2.64	1.286
	PPT with Narration2	4 (33.3)	4 (33.3)	3 (25.0)	1 (8.3)	2.92	0.996
	Video Capture	2 (16.7)	3 (25.0)	1 (8.3)	3 (25.0)	2.44	1.236
	Explain Everything	2 (16.7)	3 (25.0)	4 (33.3)	1 (8.3)	2.60	0.966
Q6d Watching the video was a great way to learn about math.	PPT with Narration1	5 (41.7)	3 (25.0)	3 (25.0)		3.18	0.874
	Screen Capture of App	1 (8.3)	7 (58.3)	3 (25.0)	1 (8.3)	2.67	0.778
	Internet-Accessed	1 (8.3)	5 (41.7)	4 (33.3)	1 (8.3)	2.55	0.820
	PPT with Narration2	1 (8.3)	4 (33.3)	6 (50.0)		2.50	0.798
	Video Capture		5 (41.7)	3 (25.0)	1 (8.3)	2.63	0.518
	Explain Everything		2 (16.7)	7 (58.3)	1 (8.3)	2.10	0.568
Q6e I felt bored watching the content.	PPT with Narration1	1 (8.3)	2 (16.7)	5 (41.7)	3 (25.0)	2.91	0.944
	Screen Capture of App	5 (41.7)		6 (50.0)	1 (8.3)	2.25	1.138
	Internet-Accessed	1 (8.3)	2 (16.7)	4 (33.3)	3 (25.0)	2.90	0.994

	PPT with Narration2	4 (33.3)		8 (66.7)	2 (16.7)	2.33	0.985
	Video Capture		1 (8.3)	5 (41.7)		3.13	0.641
	Explain Everything		3 (25.0)	6 (50.0)	1 (8.3)	2.80	0.632
Q6f The video was just okay.	PPT with Narration1	1 (8.3)	1 (8.3)	5 (41.7)	4 (33.3)	1.91	0.944
	Screen Capture of App	4 (33.3)	1 (8.3)	5 (41.7)	2 (16.7)	2.58	1.165
	Internet-Accessed	1 (8.3)	4 (33.3)	3 (25.0)	3 (25.0)	2.27	1.009
	PPT with Narration2	1 (8.3)	4 (33.3)	5 (41.7)	2 (16.7)	2.33	0.888
	Video Capture			6 (50.0)	2 (16.7)	1.75	0.463
	Explain Everything	1 (8.3)	4 (33.3)	3 (25.0)	2 (16.7)	2.40	0.966
Q6g I would prefer to learn the math from an instructor.	PPT with Narration1		3 (25.0)	4 (33.3)	4 (33.3)	3.09	0.831
	Screen Capture of App	2 (16.7)	1 (8.3)	6 (50.0)	3 (25.0)	2.83	1.030
	Internet-Accessed	2 (16.7)	5 (41.7)	1 (8.3)	3 (25.0)	2.45	1.128
	PPT with Narration2	3 (25.0)	3 (25.0)	2 (16.7)	4 (33.3)	2.58	1.240
	Video Capture	1 (8.3)	3 (25.0)		5 (41.7)	3.00	1.225
	Explain Everything	1 (8.3)	5 (41.7)	2 (16.7)	2 (16.7)	2.50	0.972
Q6h I enjoyed thinking about math while I watched the video.	PPT with Narration1		8 (66.7)		3 (25.0)	2.45	0.934
	Screen Capture of App	1 (8.3)	1 (8.3)	9 (75.0)	2 (16.7)	1.92	0.515
	Internet-Accessed	1 (8.3)		6 (50.0)	4 (33.3)	1.82	0.874
	PPT with Narration2		1 (8.3)	7 (58.3)	3 (25.0)	2.00	0.853
	Video Capture		2 (16.7)	5 (41.7)	1 (8.3)	2.13	0.641
	Explain Everything		3 (25.0)	6 (50.0)	1 (8.3)	2.20	0.632
Q6i While watching	PPT with Narration1	3 (25.0)	5 (41.7)	2 (16.7)	1 (8.3)	2.91	0.944
		4	6	1	1		

the video it was important to me that I understood the math really well.	Screen Capture of App	(33.3)	(50.0)	(8.3)	(8.3)	3.08	0.900
	Internet-Accessed	1 (8.3)	5 (41.7)	2 (16.7)	3 (25.0)	2.36	1.027
	PPT with Narration2	1 (8.3)	5 (41.7)	4 (33.3)	2 (16.7)	2.42	0.900
	Video Capture	1 (8.3)	6 (50.0)	1 (8.3)	1 (8.3)	2.78	0.833
	Explain Everything		2 (16.7)	8 (66.7)		2.20	0.422
Q6j I tried to learn as much math I could while watching the video.	PPT with Narration1	5 (41.7)	4 (33.3)	1 (8.3)	1 (8.3)	3.18	0.982
	Screen Capture of App	2 (16.7)	5 (41.7)	4 (33.3)	1 (8.3)	2.67	0.888
	Internet-Accessed		4 (33.3)	5 (41.7)	2 (16.7)	2.18	0.751
	PPT with Narration2	1 (8.3)	7 (58.3)	4 (33.3)	1 (8.3)	2.50	0.674
	Video Capture		4 (33.3)	3 (25.0)		2.75	0.707
	Explain Everything		3 (25.0)	7 (58.3)		2.30	0.483
Q6k While watching the video I felt that learning math was interesting.	PPT with Narration1	1 (8.3)	5 (41.7)	4 (33.3)	1 (8.3)	2.55	0.820
	Screen Capture of App		3 (25.0)	5 (41.7)	4 (33.3)	1.92	0.793
	Internet-Accessed		2 (16.7)	7 (58.3)	2 (16.7)	2.00	0.632
	PPT with Narration2		3 (25.0)	7 (58.3)	2 (16.7)	2.08	0.669
	Video Capture		5 (41.7)	2 (16.7)	2 (16.7)	2.33	0.866
	Explain Everything		2 (16.7)	8 (66.7)		2.20	0.422
Q6l While I was watching the video, I liked the feeling of solving problems.	PPT with Narration1	4 (33.3)	4 (33.3)	2 (16.7)	1 (8.3)	3.00	1.00
	Screen Capture of App	2 (16.7)	1 (8.3)	6 (50.0)	3 (25.0)	2.17	1.030
	Internet-Accessed	1 (8.3)	3 (25.0)	3 (25.0)	4 (33.3)	2.09	1.044
	PPT with Narration2	1 (8.3)	2 (16.7)	7 (58.3)	2 (16.7)	2.33	0.835
	Video Capture	1 (8.3)	3 (25.0)	3 (25.0)	2 (16.7)	2.60	1.00
		2	2	6			

	Explain Everything	(16.7)	(16.7)	(50.0)			0.843
Q6m While watching the video, I did a lot of thinking.	PPT with Narration1	1 (8.3)	5 (41.7)	4 (33.3)	1 (8.3)	2.55	0.820
	Screen Capture of App		3 (25.0)	4 (33.3)	5 (41.7)	1.83	0.835
	Internet-Accessed			5 (41.7)	5 (41.7)	1.50	0.527
	PPT with Narration2		1 (8.3)	8 (66.7)	2 (16.7)	2.00	0.775
	Video Capture		3 (25.0)	2 (16.7)	4 (33.3)	1.89	0.928
	Explain Everything		1 (8.3)	5 (41.7)	4 (33.3)	1.70	0.675
Q6n Too much informatio n was presented in the video.	PPT with Narration1	10 (83.3)	1 (8.3)			1.09	0.302
	Screen Capture of App	10 (83.3)	2 (16.7)			1.17	0.389
	Internet-Accessed	11 (91.7)	1 (8.3)			1.00	0.000
	PPT with Narration2	9 (75.0)	1 (8.3)	2 (16.7)		1.42	0.793
	Video Capture	6 (50.0)	2 (16.7)			1.25	0.463
	Explain Everything	9 (75.0)		1 (8.3)		1.20	0.632
Q6o I would rather work on practice questions than watch a video for homewor k in math.	PPT with Narration1	5 (41.7)	4 (33.3)	2 (16.7)		1.73	0.786
	Screen Capture of App	5 (41.7)	3 (25.0)	1 (8.3)	3 (25.0)	2.17	1.267
	Internet-Accessed	3 (25.0)	3 (25.0)	3 (25.0)	2 (16.7)	2.36	1.120
	PPT with Narration2	5 (41.7)	2 (16.7)	5 (41.7)		2.00	0.953
	Video Capture	3 (25.0)	3 (25.0)	3 (25.0)		2.00	0.866
	Explain Everything	2 (16.7)	3 (25.0)	4 (33.3)	1 (8.3)	2.40	0.966

Note: Scores in brackets are measured in percent.

Table D.3

Frequency Table of Aspects that were Helpful in Learning Mathematics (Overall Feedback Survey – Item #2)

Item # 2 – Overall Feedback Survey	4 Strongly Agree	3	2	1 Strongly Disagree	*SD*	*M*
Item 2a The recap (or summary) at the end of the video helped me remember what I learned in the video.	6 (50.0)	4 (33.3)	1 (8.3)		0.688	3.45
Item 2b Background music was a nice touch.		5 (50.0)	4 (33.3)	2 (16.7)	0.778	2.33
Item 2c The opportunity to pause and practice the math was helpful.	8 (66.7)	3 (25.0)	1 (8.3)		0.669	3.58
Item 2d Hand-writing on the video is just as good as typed text/numbers.	3 (25.0)	4 (33.3)	3 (25.0)	2 (16.7)	1.073	2.67
Item 2e Background music was distracting.	2 (16.7)	5 (41.7)	2 (16.7)	3 (25.0)	1.087	2.50
Item 2f Animation (character moving across the screen or poof of smoke) is entertaining		6 (50.0)	6 (50.0)		0.522	2.50
Item 2g An exercise sheet at the end of the video would be just as good as having practice questions within the video.	5 (41.7)	1 (8.3)	5 (41.7)	1 (8.3)	1.115	2.83
Item 2h Typed text/numbers is neat and easy to read.	6 (50.0)	3 (25.0)	2 (16.7)		0.809	3.36
Item 2i Video creators should avoid handwriting because it is too messy.	5 (41.7)	3 (25.0)	1 (8.3)	3 (25.0)	1.267	2.83
Item 2j Instructional videos for challenging concepts is very helpful.	5 (41.7)	4 (33.3)	2 (16.7)	1 (8.3)	.996	3.08
Item 2k Fancy features (animations, music, etc) are irrelevant as long as a video teaches the math well.	3 (25.0)	4 (33.3)	4 (33.3)	1 (8.3)	0.965	2.75
Item 2l The addition of practice problems to try on	4 (33.3)	5 (41.7)	3 (25.0)		0.793	3.08

my own helped me learn the math.						
Item 2m The recap (or summary) at the end of the video helped me to retain what I learned in the video.	7 (58.3)	4 (33.3)	1 (8.3)		0.674	3.50

Note: Scores in brackets are measured in percent.

Table D.4

Frequency Table of the Effectiveness and Use of Instructional Videos for Teaching Mathematics (Overall Feedback Survey Item #4)

Item #4 – Overall Feedback Survey	4 Yes, Very True	3 True	2 A little true	1 No, not at all true	*SD*	*M*
Item 4a A course with instructional videos is better than a course without videos.	4 (33.3)	4 (33.3)	3 (25.0)		0.831	3.09
Item 4b I prefer to do practice problems for math homework than watch a video.	1 (8.3)	4 (33.3)	4 (33.3)	2 (16.7)	0.924	2.36
Item 4c I believe that the instructional videos helped me learn more	3 (25.0)	5 (41.7)	3 (25.0)		0.775	3.00
Item 4d Learning math through an instructional video is an effective way to learn math.	3 (25.0)	6 (50.0)	2 (16.7)		0.701	3.09
Item 4e Effective instructional videos used to teach math must include practice problems for the viewer.	6 (50.0)	4 (33.3)	1 (8.3)		0.688	3.45
Item 4f Effective instructional videos that present more challenging content are more engaging.	3 (25.0)	2 (16.7)	5 (41.7)	1 (8.3)	1.027	2.64
Item 4g Instructional videos that summarize key ideas at the end are more effective.	7 (58.3)	3 (25.0)	1 (8.3)		0.688	3.55
Item 4h Instructional videos that include some humour, such as gifs or pop references, are more engaging.	1 (8.3)	5 (41.7)	4 (33.3)	1 (8.3)	0.820	2.55
Item 4i Instructional videos that are short and quick to a point are more effective.	4 (33.3)	4 (33.3)	3 (25.0)		0.831	3.09
Item 4j Instructional videos should be avoided.				11 (91.7)	0.000	1.00
Item 4k Overall, instructional videos are an	5 (41.7)	5 (41.7)	1 (8.3)		0.674	3.36

effective way to learn math.						
Item 4l Instructional videos should <u>not</u> be used to learn mathematical concepts.				11 (91.7)	0.000	1.00
Item 4m If the concepts presented in the video was too easy, I tuned out.	3 (25.0)	2 (16.7)	6 (50.0)		0.905	2.73
Item 4n If the concepts presented in the video was too hard, I tuned out.	3 (25.0)	1 (8.3)	4 (33.3)	3 (25.0)	1.206	2.36
Item 4o Entertaining features are needed to keep me interested in the video.		1 (8.3)	4 (33.3)	6 (50.0)	0.688	1.55
Item 4p The instructional video prepared me for class.	4 (33.3)	1 (8.3)	6 (50.0)		0.982	2.82

Note: Scores in brackets are measured in percent.

Table D.5

Frequency Table of Student Rating of Video Design Formats (Overall Feedback Survey Item #3)

Video Design Formats	5 "Best format…"	4	3	2	1 "Not a good format…"	*SD*	*M*
PPT with Narration	7(58.3)	4(33.3)		1(8.3)		0.900	4.42
Internet-Accessed	1(8.3)	2(16.7)	6(50.0)	2(16.7)	1(8.3)	1.044	3.00
Screen Capture of App	2(16.7)	3(25.0)	2(16.7)	4(33.)		1.191	3.27
Explain Everything App	2(16.7)	1(8.3)	2(16.7)	3(25.0)	2(16.7)	1.476	2.80
Video Capture	3(25.0)		3(25.0)	2(16.7)	2(16.7)	1.583	3.00

Note: Scores in brackets are measured in percent.

Appendix E

Inferential Statistics Summary

Table E.1

Friedman Mean Rank

Production Style	Mean Rank
PPT with Narration1	5.64
Screencast of App	3.43
Internet-Accessed	2.57
PPT with Narration2	2.21
Video Capture	3.79
Explain Everything App	3.36

Table E.2

Friedman Test Statistics

Variable	Statistic
N	7
Chi-Square	14.85
df	5
Asymp. Sig.	0.011

Table E.3

Wilcoxon Signed-Rank Test (p-values)

	PPTNar1	ScreenCap	InterAcc	PPTNar2	VideoCap	ExpEvery
PPTNar1		0.083	0.005	0.009	0.027	0.011
ScreenCap			0.091	0.209	1.000	0.168
InterAcc				0.308	0.206	0.102
PPTNar2					0.441	1.00
VideoCap						0.553
ExpEvery						

Table E.4

Holm-Bonferroni Adjustment

p-values in order of small to big		Number of comparisons – 1_n		Modified p-value	
InterAcc: 0.005	X	5	=	0.025	p<0.05, reject null hypothesis
PPTNar2: 0.009	X	4	=	0.036	p<0.05, reject null hypothesis
ExpEver: 0.011	X	3	=	0.033	p<0.05, reject null hypothesis
VidCapt: 0.027	X	2	=	0.054	p>0.05, accept null hypothesis
ScrnCapt: 0.083	X	1	=	0.083	p>0.05, accept null hypothesis