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The Effects of Problem-Based Learning on Mathematics Motivation in a Flipped Classroom Instructional Environment

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THE EFFECTS OF PROBLEM-BASED LEARNING ON MATHEMATICS MOTIVATION IN A FLIPPED CLASSROOM INSTRUCTIONAL ENVIRONMENT

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DEDICATION

To my wife, Ana, you are the reason that I have become the man that I am. Your support for all of my endeavors and my crazy schedule has always been unwavering. I promise that I am not planning more crazy ideas, like teaching, being on city council, owning a gym, coaching basketball, getting my Master's degree, getting my Doctorate, etc., all at the same time. To my son, Kendall, I know that it is hard for you to understand, but daddy does all of this studying to make a better life for you. I want you to be able to experience the world. I also hope that I have been an inspiration for your life. You can accomplish anything, but it requires great sacrifice and often requires more work than you think you can endure.

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ABSTRACT

In response to decreasing motivation in high school math classrooms, teachers are transforming classrooms with various instructional techniques. Traditional math instruction relies on direct instruction and memorization of content, processes, and skills. Teachers are transitioning to more constructivist student-led approaches. Utilizing multiple instructional designs provides teachers more opportunities to access the major components of the ARCS Model: attention, relevance, confidence, and satisfaction.

Therefore, the purpose of this action research was examining problem-based learning in a flipped classroom instructional environment and measuring its effect on students' motivation and achievement in Algebra 2. The study addressed the following research questions: 1) What is the impact of problem-based learning in a flipped classroom instructional environment on students' motivation in mathematics?; 2) What is the impact of problem-based learning in a flipped classroom instructional environment on students' self-efficacy in mathematics?; 3) What is the impact of problem-based learning in a flipped classroom instructional environment on students' mathematics achievement on Systems of Equations and Quadratic Functions?; and 4) What are students' perceptions of problem-based learning in a flipped classroom instructional environment?

The action research innovation lasted seven weeks. Students responded to a Motivation in Mathematics Survey and answered items from a Diagnostic Test on Systems of Equations and Quadratic Functions, before and after the innovation period. Students' diagnostic test scores showed a significant increase ($t(21) = 4.75$, $p < .001$, Cohen's $d = 1.01$) from preinnovation to postinnovation measures. However, students' overall motivation ($t(21) = .91$, $p = .187$) and self-efficacy subscale scores ($t(21) = 1.69$, $p = .053$) on the motivation survey were not significantly different. Students also participated in interviews and math journals, in conjunction with teacher observations. Findings were analyzed to establish five themes: 1) Students desired more traditional structure than problem-based learning in a flipped classroom.; 2) Problem-based learning was time consuming and prevented practicing math skills.; 3) The encouragement and effort of their teacher positively affected their motivation more than other factors.; 4) Motivation was lower due to time required and time of the school year.; and 5) Students developed real-world skills through engaging, relevant, and high value tasks.

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CHAPTER 1

INTRODUCTION

National Context

Students' interest in mathematics is waning. Ninety percent of high school graduates did not have any interest in a STEM career (The Editorial Board, 2013), and of those that did have an interest, 60% transferred out of STEM careers (Lloyd, 2018). Among high school graduates, only 53% of females and 59% percent of males claimed to like math (Cunningham, Hoyer, & Sparks, 2015). Student motivation for mathematics needs to be reignited. Morrison, Ross, Kalman, and Kemp (2013) stated that many instructors believed learner motivation influenced students' success more than any other factor. The "*I don't care*" attitude is very prevalent in high school Algebra 2 students. Student motivation to engage in learning had been linked to better grades and persistence (Fredricks & McColskey, 2012; Kuh, Kinzie, Buckley, Bridges, & Hayek, 2006; Lei, Cui, & Zhou, 2018). Corso, Bundick, Quaglia, and Haywood (2013) pointed to future life success derived from engagement in class, but remarked on its difficulty to measure. If students allow their lack of interest and motivation to lead to failure, they endanger several hundred thousand dollars in future income (Stark, Noel, & McFarland, 2015).

According to Cunningham et al. (2015), 73.5% of male high school graduates and 77.7% of female high school graduates earned credit for Algebra 2. It is concerning that there is not a higher percentage of high school graduates earning Algebra 2 credit. It is related very closely to College Algebra, and it is a necessary prerequisite to STEM careers. Stoker, Mellor, and Sullivan (2018) also reported a completion rate around 78% for students in their local high school. The failure rates hovered between 14-17%, and Hispanic and African-American students suffered the highest failure rates (Stoker et al., 2018).

High school mathematics classrooms are facing a serious problem, as students are not motivated in classrooms (Skinner, Furrer, Marchand, & Kindermann, 2008). Most notable were transitions to middle school and high school (Skinner et al., 2008). Ozkal (2019) also claimed that students' motivation was on a continual decline from preschool through high school. Ozkal (2019) stated that students may have been present in the classroom, but were not interested in participating in mathematics.

One approach to bring variability to classrooms is changing the instructional approach from teacher-centered to more student-centered (Markušić & Sabljić, 2019). There have been calls for reforming instruction in mathematics for decades (Kalaian, Kasim, & Nims, 2018). Instruction in mathematics does not look like the real world (The Editorial Board, 2013). Chua, Tan, and Liu (2016) emphasized that education needed to keep up with the complexities of the world. Some teachers are experimenting with problem-based learning as a possible agent of change (Cetin, Mirasyedioglu, & Cakiroglu, 2019; Chua et al., 2016; Fukuzawa, Boyd, & Cahn, 2017; Ghufron & Ermawati, 2018; Markušić & Sabljić, 2019). Chua et al. (2016) state, "It is not how much content we disseminate in the classroom that matters but rather the learning process that engages students' motivation and independent learning" (p. 20).

In addition, teachers can create more individualized learning environments through the use of technology-mediated instruction (O'Byrne & Pytash, 2015).

According to O'Byrne and Pytash (2015), teachers are utilizing differing levels of face-to-face instruction and technology-mediated instruction. Kalonde (2017a) emphasizes that national and local organizations are encouraging technology integration in classrooms. Dinc (2019) also references the US Department of Education guiding the innovative and equitable implementation of technology into classrooms.

Local Context

Algebra 2 involves very complex topics. Some of my students are unprepared, because they are forced to think and problem-solve more than they are accustomed to attempting. Even with the high complexity of the concepts and procedures, I still believe 20% of my students should be able to maintain an average of 80 or above. Last year, I had four students maintain a 90 or above and 10 students maintain an 80 to 89. That was 14 out of 74, or 18.9%, that met my performance goal. While it was not far from my goal of 20%, it had been steadily declining over the previous five years. I was also concerned, because a 23% failure rate last year marked my highest number of Algebra 2 failures as a teacher. This failure rate is unacceptable for my classroom. My students are struggling to perform on complex math topics. Failure rates for other math teachers at Pali High School are similar. Their students are also disengaged and unmotivated. It is not uncommon to walk the halls of Pali High and see sleeping students in every classroom.

My students routinely ask, "*Why do we need to know this stuff?*" Students do not seem to see a purpose for school, especially math. Failing to see that education is related to their lives can lead to a lack of motivation and engagement in classrooms (Fukuzawa et al., 2017). Students are bored with traditional mathematics instruction. I have always endeavored to make math class as engaging as possible, but it was time for me to try a different instructional design. As Chua et al. (2016) and Kalaian et al. (2018) emphasized, my math instruction needed reform. Transforming instruction from traditional teacher-centered instruction to student-centered problem-based learning in a flipped classroom went against the status quo at Pali High School. I was interested to examine impacts of instructional change in my classroom. Corso et al. (2013) indicated that better student motivation reignited teachers' passion as well.

As a district, Pali County encourages teachers to be innovative with instructional methods, but there is still a heavy reliance on breadth instead of depth in standards. Much of the reliance on a wide variety of standards originates from state and federal mandates (Lee & Wu, 2017). While standards are necessary for guiding and measuring student performance, teachers feel increased pressure to cover all of the topics, at the expense of in-depth problem solving. This pressure to cover all of the topics leads many teachers to settle upon traditional lecturing methods in math classrooms, further exacerbating student motivation problems.

Statement of the Problem

Algebra 2 students at Pali High School are unmotivated in mathematics classrooms. Motivation is the driving force behind students' classroom behaviors, and many instructors feel learner motivation is the preeminent influence on student success (Morrison et al., 2013). Skinner et al. (2008) noted that research displayed a "steady decline in students' engagement with schooling, including their interest, enthusiasm, and intrinsic motivation for learning in school" (p. 765). Researchers argued that declining motivation, particularly at the high school level, originated with teachers not implementing authentic problem-solving in mathematics classrooms (Lloyd, 2018; Ozkal, 2019; Skinner et al., 2008; The Editorial Board, 2013). According to Markušić and Sabljić (2019), problem-based learning represented a radical shift from traditional teaching and rigid focus on content delivery, to an active learning atmosphere filled with students solving real-world problems and researching. Ghufron and Ermawati (2018) related problem-based learning and motivation in an Indonesian EFL class. Cetin et al. (2019) performed a case study on problem-based learning and students' attitudes towards mathematics, and suggested more research is needed on links between problem-based learning and its outcomes in mathematics classrooms. In addition, teachers can create more individualized learning environments by utilizing differing levels of face-to-face and technology-mediated instruction (O'Byrne & Pytash, 2015).

Purpose Statement

Therefore, the purpose of this action research was examining problem-based learning in a flipped classroom instructional environment and measuring its effect on students' motivation and achievement in Algebra 2 at Pali High School.

Research Questions

This study addressed the following research questions:

1) What is the impact of problem-based learning in a flipped classroom instructional environment on students' motivation in mathematics?
2) What is the impact of problem-based learning in a flipped classroom instructional environment on students' self-efficacy in mathematics?
3) What is the impact of problem-based learning in a flipped classroom instructional environment on students' mathematics achievement on Systems of Equations and Quadratic Functions?

4) What are students' perceptions of problem-based learning in a flipped classroom instructional environment?

Statement of Researcher Subjectivities and Positionality

Creswell and Creswell (2018) emphasize that during research, "the inquirer is typically involved in a sustained and intensive experience with participants" (p. 183). Because of this intimacy and the interpretive nature of research, it is important for researchers to understand their subjectivities and positionality. Researchers must also understand the effects of these two on their research.

Peshkin (1988) points out that subjectivities are qualities that affect a researchers' examination of participants. I am a middle-class white male. I have been a part of the middle-class socioeconomic status my entire life. As with any socioeconomic status, race, or gender, it is a challenge to understand how others experience life. Every attempt was made to stay objective and be a listener first. I endeavored to accurately record all observations and interviews to maintain the validity and reliability of data. Accurate recording also helped alleviate bias, but complete eradication was impossible as I viewed the world through my own paradigms (Peshkin, 1988).

Students of all backgrounds received the same treatment during the study. Although race can be a potential source of bias in studies, my particular study on motivation in Algebra 2 classrooms was not impacted by any racial bias. Thankfully, my parents taught me to observe the heart and intentions of another human versus their skin. While many mathematics techniques did not need adaptation, I utilized a variety of methods to teach technique. Cooperative learning was one method noted by research (Banks, 2016; Ghufron & Ermawati, 2018; Kalaian et al., 2018). Students with different cultural backgrounds may respond better to cooperative learning versus the traditional lone competitor style of instruction. All students had access to extra assistance from me. I also offered time for students who needed access to technology not available at home. Students with disabilities received accommodations according to individual needs.

The Pali community has been my home for nearly 85% of my life. I have been in the Pali school system as a student or teacher for 34 total years. Familiarity with Pali gave me the ability to understand my students' predispositions in classrooms, although the generational gap gave me enough separation to perform research objectively. I was able to approach the study similarly to an outsider. While my shared experiences with my students enhanced openness and candor, I was not wary of asking difficult questions (Merriam et al., 2001).

Intellectually, I am a self-proclaimed nerd. Although I try to convince my students that nerds rule the world, I know many of my students do not share the same passion for learning as myself. During my research, I always kept this thought in mind as I studied my students' motivation. Their responses may not have been what I wanted to hear, but my research findings flowed from their data.

Januszewski and Molenda (2016) defined Educational Technology as "the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources" (p. 1). I do not feel that educational technologies are the panacea to all of education's problems. Regardless of my feelings, I realize technology is a driving force in the world. My students deserve my commitment to relinquishing my control tendencies and allowing them freedom and choice in their avenues of learning. My research on problem-based learning in a flipped classroom instructional environment allowed me to put my subjectivities aside and allowed my students to construct their own learning. Stepping aside allowed me to truly observe effects on motivation.

Finally, researchers must understand their positionality during a study. During action research, relationships between researchers and participants are very different from traditional research (Mertler, 2019). Herr and Anderson (2005) outlined a continuum from insider to outsider for researchers. Because I was directly involved in an innovation for my Algebra 2 classroom and studied how it affected my personal practice, Herr and Anderson (2005) would designate me as an insider. My relationship was monitored to ensure my research role did not hinder my primary role of educator. Reflections were made in my researcher's journal. I also requested other teachers and administrators to observe my class as an outside critique of these roles. My goal was objectively observing and letting the actual data guide research versus concocting favorable results.

Definition of Terms

Motivation. Dimitroff, Dimitroff, and Alhashimi (2018) alluded to the fact that it is a metaphysical concept explaining why individuals take certain actions. Defining motivation, and what we attribute it to, can be a point of contention (Dimitroff et al., 2018; Keller, 1987; Yurt, 2015). Motivation can have internal loci of control, as well as external (Hornstra, Kamsteeg, Pot, & Verheij, 2018). Motivation is the driving force behind what individuals choose to do and what makes them sustain effort (Dimitroff et al., 2018; Thaer & Thaer, 2016). For this study, motivation was defined as an intrinsic or extrinsic force that initiates, guides, and sustains activities or behaviors aimed at achieving a goal (Deci & Ryan, 1985; Dimitroff et al., 2018; Hornstra et al., 2018; Yurt, 2015).

Self-efficacy. Students who are confident in their ability to accomplish math tasks are more likely to be motivated to engage in high level thinking and increase their achievement (Hwang, 2016). This feeling is defined by researchers as self-efficacy, or competence beliefs in abilities (Jiang, Rosenzweig, & Gaspard, 2018). Hwang (2016) identified self-efficacy as a motivational construct closely related to the confidence category from the ARCS model. Fear of failing can cause a lack in confidence and low self-efficacy (Keller, 1987). For this study, self-efficacy was defined as an internal belief that one can succeed at a task (Deci & Ryan, 1985; Jiang et al., 2018).

Problem-Based Learning. Fukuzawa et al. (2017) described problem-based learning as an avenue providing students with real-world problem-solving skills. Problem-based learning is intended to be open-ended, ill-structured, and comparable to real-world problem-solving models (Barrows & Tamblyn, 1980; Ghufron & Ermawati, 2018; Hmelo-Silver, 2004; Savery, 2006). Problems can apply learning from class directly to real-world scenarios, or incite students to research and construct their own knowledge (Barrows & Tamblyn, 1980; Fukuzawa et al., 2017). Hmelo-Silver (2013) states that problems can support extensive learning but not cover every aspect of specific course learning. It is not always content driven, but can connect directly with curriculum concepts (Hmelo-Silver, 2013). For this study, problem-based learning was defined as instruction facilitated by real-world scenarios with open-ended solutions or application of algebraic concepts.

Traditional Instruction. Traditional mathematics instruction is teacher-centered and primarily focuses on disseminating information from teacher to student. Traditional instruction is typically marked by lecture and rigid content delivery (Markušić & Sabljić, 2019). Teachers are experts, and students are novices. Ornstein and Hunkins (2017) labeled this type of instruction as either lecture or direct instruction. Lecture and direct instruction are two different instructional approaches (Magliaro, Lockee, & Burton, 2005). For this study, traditional instruction was defined as delivering mathematics content through lecture or direct instruction (Magliaro et al., 2005; Ornstein & Hunkins, 2017).

Flipped Classroom Instruction. Traditional instruction primarily places teacher-centered delivery of content in the classroom and student practice at home (Amstelveen, 2019; Magliaro et al., 2005). Teachers are choosing to completely turn this scenario around, thus the term: *the Flipped Classroom*. Amstelveen (2019) defined flipped classrooms as those where students studied lessons through video or other media at home, then classwork and practice during actual seat time with instructors. The premise of flipping the classroom was occurring before the term was even coined, whenever teachers placed educational events typically happening within the classroom at home and vice versa (Eppard & Rochdi, 2017). There is not a large amount of argument about the definition of a flipped classroom. For this study, the definition of the flipped classroom was lessons occurring through video at home followed by practice or application in class (Amstelveen, 2019; Eppard & Rochdi, 2017).

Student Perceptions. Transitioning to more student-centered and active learning designs creates different classroom experiences for students (Tendhar, Singh, & Jones, 2019). Mixed methods action research provides the ability to discern students' observations of their lived experiences along with quantitative data (Creswell & Creswell, 2018; Schoonenboom & Johnson, 2017; Thomas, 2006). Qualitative data sources provided indications of how problem-based learning in a flipped classroom was perceived by my students. Students' perceptions were defined as the lived experiences of my students during the innovation.

Student Achievement. For this study, achievement was strictly measured on an objective performance assessment covering Systems of Equations and Quadratic Functions. Because it was specific to performance, it was not a measurement of overall learning. According to Alexander, Schallert, and Reynolds (2009), "Learning is a multidimensional process that results in a relatively enduring change in a person or persons, and consequently how that person or persons will perceive the world and reciprocally respond to its affordances physically, psychologically, and socially" (p. 186). Learning is long lasting. It is a permanent change in how students interact with their surroundings, not just recall of information (Alexander et al., 2009). Performance, instead, is recalling information or remembering how to do tasks. Performance measurements are only one indicator of achievement, as good performance can occur without actual learning taking place (Soderstrom & Bjork, 2015). Students displayed their abilities to solve math problems, but applying their abilities in different situations is very different. Measuring long lasting learning was not within the scope of this study. Soderstrom and Bjork (2015) indicated performance as what is actually observed and measured during instruction.

Blended Learning. Flipped classrooms, consisting of instruction at home and enrichment at school, have gained popularity (Amstelveen, 2019). Classroom technology integration is increasing in a variety of formats and being encouraged on the national stage (Dinc, 2019; Kalonde, 2017a, 2017b). O'Byrne and Pytash (2015) point out that teachers can and should use a variety of face-to-face and technology-mediated instruction. Teachers find a balance between many different forms of instruction. This type of instruction is called hybrid learning or blended learning (O'Byrne & Pytash, 2015; Simonson, Smaldino, & Zvacek, 2014). For this study, blended learning was defined as combining direct instruction, flipped instruction, technology-enhanced instruction, and problem-based learning.

CHAPTER 2

LITERATURE REVIEW

The purpose of this action research was examining problem-based learning in a flipped classroom instructional environment and measuring its effect on students' motivation and achievement in Algebra 2 at Pali High School. The review of literature examines research that relates to the following research questions: 1) What is the impact of problem-based learning in a flipped classroom instructional environment on students' motivation in mathematics?; 2) What is the impact of problem-based learning in a flipped classroom instructional environment on students' self-efficacy in mathematics?; 3) What is the impact of problem-based learning in a flipped classroom instructional environment on students' mathematics achievement on Systems of Equations and Quadratic Functions?; and 4) What are students' perceptions of problem-based learning in a flipped classroom instructional environment?

The literature review was conducted by considering topics that related to the research questions and provided a framework for this study. The primary databases utilized for the literature search were ERIC, JSTOR, ProQuest, Google Scholar, National Center for Education Statistics, and embedded databases within the USC Library system. The following keywords, and various combinations of the keywords, were employed: problem-based learning, motivation, mathematics, measuring motivation, motivated strategies for learning questionnaire, student attitude towards mathematics, ARCS Model, direct instruction, flipped classroom, flipped instruction, hybrid instruction, blended instruction, technology-mediated, technology, integration, Algebra 2, trends in high school mathematics, educational technology, real-world math, and problem solving. Textbooks and journal articles that were recommended by professors during my doctoral program of study, were also utilized. Finally, there was a wealth of resources to mine from initial findings' reference pages.

The literature review is organized into four major sections: (a) motivation in classrooms, (b) traditional mathematics instruction, (c) problem-based learning, and (d) technology-enhanced lessons.

Motivation in Classrooms

This section provides an overview of the main variable being examined during this research. It begins with a definition of motivation, curated from various research perspectives. Then, the benefits of motivation in classrooms are outlined. Finally, I discuss the lack of motivation problem.

Defining Motivation and Conditions for Motivation

Motivation can drive individuals to achieve feats that are necessary, or even seemingly unattainable. The classroom does not differ from the outside world, but defining motivation can be challenging. Defining motivation can be a point of contention, and deciding who is responsible for motivation can incite countless arguments (Dimitroff et al., 2018; Keller, 1987; Yurt, 2015). The question often centers around motivation originating from internal forces within students or from external forces in students' environments. Deci and Ryan (1985) claimed that the study of motivation investigated what invigorates and guides behavior. Self-Determination Theory divides motivation into intrinsic (internal) and extrinsic (external) drives to start and complete tasks (Nenthien & Loima, 2016). Students can be motivated by an internal desire to learn. Learning is exciting, and they find interest in the topics being discussed. Intrinsic motivation causes students to engage in activities for their pleasurable experience (Hornstra et al., 2018). Alternatively, students can be motivated by their environmental pressures. Students have parents that want them to pass or excel in a class. They also know that they need the class to advance to the next school level. Students can even react to their teacher's praise. Teachers' praise can instill a belief that they are competent at completing tasks (Hornstra et al., 2018).

Whether one believes that motivation is intrinsically driven or extrinsically driven, both sides can agree that motivation is a metaphysical concept explaining why individuals take certain actions (Dimitroff et al., 2018). Motivation is the driving force behind what individuals choose to do and what makes them sustain effort. Along with this belief, Kiefer, Alley, and Ellerbrock (2015) noted that motivation drives and sustains behavior leading to school success. Students make the choice to complete an assignment. They sustain effort, even when the work becomes difficult. Skinner et al. (2008) pointed out that motivation is marked by exertion and persistence.

Additionally, Attard (2012) states that "a student's motivations determine whether or not he or she will engage in a particular pursuit" (p. 10). The concept of engagement was prevalent in the literature. Although authors pointed out that motivation and engagement were two separate constructs, they also emphasized the direct relationship between the two (Fredricks & McColskey, 2012; Ozkal, 2019; Saeed & Zyngier, 2012). Engagement is what teachers observe in their classrooms, because it is the outward display of motivated students choosing to participate behaviorally, emotionally, and cognitively (Fredricks & McColskey, 2012; Ozkal, 2019). Branom (2013) would argue that motivation deals with the inner feelings toward a subject like mathematics, and engagement is the external behaviors like work completion.

Evident within these research perspectives on motivation are several common themes. Students make choices to begin a task. Students receive, or perceive, reinforcement to motivation through intrinsic and extrinsic forces that guide their behavior during tasks. Finally, student motivation causes them to persist in their tasks, regardless of difficulty. For this study, motivation was defined as an intrinsic or extrinsic force that initiates, guides, and sustains activities or behaviors aimed at achieving a goal (Deci & Ryan, 1985; Dimitroff et al., 2018; Hornstra et al., 2018; Yurt, 2015). The definition of motivation is connected to conditions that are necessary in instruction and classroom environment that encourage motivation.

The ARCS Model

The ARCS Model is a motivational theory and instructional design model that focuses on understanding students' motivation to learn (Keller, 1987). The acronym, ARCS, represents attention, relevance, confidence, and satisfaction. The arguments over locus of control for student motivation inspired Keller to provide a model for student motivation and situate it within theories of learning (Keller, 1987). Keller (1987) states that motivation is viewed as "unpredictable and changeable" (p. 2). The fact that motivation is changeable provides opportunities for teachers to design instruction to support student motivation. The unpredictability forces teachers to examine the effects of their classroom decisions.

Because of its metaphysical and primarily psychological components, motivation had not been previously studied within the context of learning theories or models (Keller, 1987). Keller decided to study how the psychological components of the expectancy-value theory, behaviorist theories, and cognitivist theories could be applied to enhancing motivation to learn (Keller, 1987). Essentially, Keller synthesized all available literature on motivation and formed a model that provided more comprehensive explanations of motivation to learn. As I discuss later, my research intended to examine motivation in the context of constructivist theories as well.

Foundations for the expectancy-value theory began with Tolman and Lewin (Keller, 1987; Lewin, 1938; Tolman, 1932). Yurt (2015) states that "according to this model, expectancy and value are two fundamental factors controlling and guiding individuals' behaviors" (p. 289). Expectancy considers whether or not humans feel able to complete a task, and value pertains to individuals seeing personal fulfillment or worth in some task (Keller, 1987; Yurt, 2015). This theory, along with behaviorist theories on reinforcement, provided the basis for the four categories in the ARCS Model. Keller stated in an interview that learning theories have areas that they explain the best, but none provided a full understanding of human behavior (Dodge, 2011). He felt his model provided a synthesis of the pertinent theories to learner motivation, and created a more complete model.

Originally, the value category was divided into interest and relevance, the expectancy category remained unchanged, and a fourth category called outcomes was included (Keller, 1987). The outcomes category stemmed from behaviorist theories, which stated that students continue behaviors that are reinforced (Driscoll, 2005; Keller, 1987; Schunk, 2016). These four categories were intended to include all theoretical concepts of motivation. Subcategories have been listed by Keller as well. Eventually, three out of the four categories received name adjustments for an easier to remember acronym: Attention (from interest), Relevance, Confidence (from expectancy), and Satisfaction (from outcomes) (Keller, 1987).

Teachers are encouraged to design their instruction to access the four categories as much as possible, in order to improve motivation (Baker & Robinson, 2017). Instruction, classroom environment, and students' materials all play a role. The ARCS Model serves a dual purpose. It gives a theoretical framework of measurable characteristics that humans develop and continue displaying during motivated work. Combining these with prescriptive changes to resources and approaches, creates an instructional design component as well. The ARCS motivational design process provided a framework for this current study's design. Beneath each of the four categories of the ARCS Model, Keller (1987) gave conditions and strategies for supporting motivation in students. Highlights of those conditions and strategies are in the following section.

Categories of ARCS model. The first category of the ARCS Model is attention. Similar to the general definition of motivation, lessons should not just gain attention, but sustain attention as well. Teachers have used various methods of gaining attention for many years. Teachers utilize vocal cues like "Listen up!", or visual cues like turning the lights on and off rapidly. Keller (1987) even mentioned a staged proclamation, such as a story, a contrived situation, or a common statement used throughout the year. Specifically, mathematics teachers can utilize some of the same techniques to gain their students' attention. It is not surprising that this category was originally called interest.

Many times, the true challenge is sustaining student interest in a topic or activity (Keller, 1987). Keeping students interested in high school mathematics classes is a tough trial for teachers. Real-world problems are a motivating factor that can make class more interesting for students (Le Roux, 2008).

The second category outlined by the ARCS Model is relevance. Although it is not unique to mathematics classrooms, math teachers are very familiar with the question, *Why do I need to know this?* Many teachers attempt to connect learning to future jobs or current situations that students enjoy (Keller, 1987). Using this technique can help students feel what they are learning is worthwhile. Students in a study by Dimitroff et al. (2018) explained they felt more motivated to learn when classroom topics were connected to their lives, hobbies, or future careers. Students who realize their math class can help to fulfill their future goals and needs become more motivated (Yurt, 2015). They realize the utility of mathematics for their lives. Seeing utility in the study of mathematics connects directly to the concept of task value. Students feel intrinsic and extrinsic motivation when their classroom tasks have direct value to their lives currently or in the future (Jiang et al., 2018). Additionally, some teachers and students find relevance in learning itself (Keller, 1987). While a classroom full of students who love and treasure learning seems like a dream come true, it may only be a fantasy. Keller (1987) states that relevance can also come from the method of teaching, not just content or love of learning. Therefore, teachers utilize a variety of instructional design techniques for their lessons.

The third ARCS category is delineated as confidence. Students who expect to succeed in a class are more motivated to work hard, even when the content becomes more challenging (Keller, 1987; Yurt, 2015). Keller (1987) mentions that confidence leads students to become more involved in tasks and appreciate learning even when mistakes are being made. Math teachers are tasked with assisting students to build confidence in mathematics. Encouraging and supportive teachers are extrinsic motivators for students (Nenthien & Loima, 2016; Yurt, 2015). In contrast, Patrick, Ryan, and Kaplan (2007) said the exact relationship cannot be known due to entwined factors. For example, student confidence can also be affected by students' personal motivational beliefs, prior academic achievement, and personal academic goals (Patrick et al., 2007). Teachers can also overdo their level of support and actually decrease motivation due to students feeling intimidated (Kiefer et al., 2015).

Students who are confident in their ability to accomplish math tasks are more likely to be motivated to engage in high level thinking and increase their achievement (Hwang, 2016). This feeling was defined by researchers as self-efficacy (Jiang et al., 2018). Self-efficacy is an internal belief that one can succeed at a task (Deci & Ryan, 1985; Jiang et al., 2018). Jiang et al. (2018) stated that ability beliefs, like self-efficacy, were the strongest predictors of engagement and achievement. Self-efficacy can be affected by a positive classroom affect (Jiang et al., 2018). Fear of failing is a significant contributor to a lack of confidence, and teachers who show students how they are succeeding or improving can greatly influence motivation in the confidence category (Keller, 1987). Another inhibitor to motivation is the concept of cost, which has a more negative connotation than self-efficacy or task value (Jiang et al., 2018). Cost can have intrinsic and extrinsic dimensions. Students feel that the internal effort level required for tasks is too high, or the external rewards do not match the effort required (Jiang et al., 2018). Cost can lead to a lack of motivated behavior, or choosing not to even attempt a task (Deci & Ryan, 1985; Jiang et al., 2018).

Satisfaction is the final category in the ARCS Model. Behaviorist reinforcement theory formed the basis for this category, but internal satisfaction also applied (Keller, 1987). As previously mentioned, students can lose motivation if rewards do not match the cost for students (Jiang et al., 2018). However, motivation to reach goals develops when individuals are given appropriate rewards and reinforcement throughout the task (Driscoll, 2005; Keller, 1987; Schunk, 2016), although this scenario is not always foolproof. Some students are intrinsically motivated to reach a certain goal, and an extrinsic reward can devalue their work and take away their control (Keller, 1987). Keller (1987) states that "the establishment of external control over an intrinsically satisfying behavior can decrease the person's enjoyment of the activity" (p. 6). Mathematics teachers have to be sensitive to when they are overcontrolling using extrinsic rewards. When students are enjoying the lesson, it would be better to allow them to have their own satisfaction. Intrinsic motivation can be increased by allowing students to have more autonomy in their learning (Fukuzawa et al., 2017). Fukuzawa et al. (2017) also emphasized that problem-based learning was a practical instructional method to allow student autonomy.

Teachers organize their classroom environment and instruction to support motivation. Classroom climates arranged by teachers can have effects on motivation (Branom, 2013). Building interest for students and making connections with the real-world encourages an intrinsic desire for students to do the work. Teachers can support student attitudes towards their success in mathematics. Students need to see the connection to their future needs, and more control in their own learning. Motivation can also be increased with pure extrinsic rewards. The following sections discuss the benefits of student motivation.

Benefits of Motivation

Motivated students are more lively and enthusiastic (Mirza & Hussain, 2014). Actively participating in a lesson is a sign that students are motivated by the lesson's value for their life and expectance to succeed (Ahmed, 2017; Yurt, 2015). As the ARCS Model emphasizes, students will become more motivated when they see relevance in their learning and feel confident that they can be successful. Fredricks and McColskey (2012) pointed out that motivated students displayed behavioral, emotional, and cognitive engagement with content. Higher levels of participation and engagement lead students to rely on the teacher to a lesser degree. Intrinsically motivated students displayed more self-direction in their work (Fukuzawa et al., 2017). Ahmed (2017) also pointed out that motivated students displayed more self-regulated learning strategies. All of these characteristics lead students to have a desire to learn. Students also exhibit perseverance. They are willing to give full effort, even in the face of adverse situations and discomfort with classroom content (Mkhize, 2017). These characteristics provide incentive for teachers to increase motivation in their students. In addition to the aforementioned characteristics, motivation improves students' engagement and achievement.

Improving student engagement. According to Fredricks and McColskey (2012), engagement involved behavioral, emotional, and cognitive components. Motivation manifests itself through engagement in tasks and learning. Although engagement is a separate metaphysical concept, several authors make a direct link between motivation and engagement (Fredricks & McColskey, 2012; Ozkal, 2019; Saeed & Zyngier, 2012). Specifically, Ozkal (2019) stated that engagement was the outward display of a motivated student. Fredricks and McColskey (2012) also stated that motivation was necessary but not the sole foundation to engagement. In contrast, Hornstra et al. (2018) found that engagement was not correlated to motivation, even though their review of literature suggested that motivation was a strong contributor towards engagement.

One characteristic previously discussed in the ARCS Model and the conditions for motivation sections is that teachers offer topics that are relevant to students' lives. Value for their lives motivates students to stay more engaged in class (Matthews, 2017). Jiang et al. (2018) corroborated the connection between task value and engagement. In addition, as students' lives become more social in nature, providing more opportunities for them to work together in problem solving can provide more relevance to their life experience. Students in a study by Mirza and Hussain (2014) indicated that they were more motivated and excited to participate in learning that gave opportunity for collaboration.

Teachers can also provide extrinsic motivation through support of students' learning and reinforcing rewards. A study into teacher support by Kiefer et al. (2015) resulted in student motivation increases and more engagement in their own learning. As students are supported by their teachers, they can become more confident in their work. The ARCS model lists confidence as a condition for motivated students. Students who are more confident in their work, or have been reinforced by teacher support, are more likely to be motivated to engage in current and future tasks (Skinner et al., 2008).

Improving student achievement. Motivation can also affect student achievement in classrooms indirectly and directly. As discussed above, motivation improves student engagement. As students become more engaged in their learning, it leads to higher achievement as well (Ozkal, 2019). Lei et al. (2018) performed a meta-analysis of literature on the topic of engagement and found that it was correlated to achievement. Hornstra et al. (2018) states that "there is widespread consensus among researchers and educators that motivation to learn is a powerful factor contributing to engagement and achievement" (p. 2), possibly one of the most important (Jiang et al., 2018).

Additionally, some instructors pointed to motivation as the preeminent determiner of success (Morrison et al., 2013). Specifically, Hwang (2016) said that there was a direct path from motivation to math performance. In a study of a secondary agriculture course, Baker and Robinson (2017) found no correlation between student motivation factors and achievement. However, Abu-Hamour and Al-Hmouz (2013) found the highest correlation between intrinsic motivation and achievement in a math classroom. This amount was followed by a lower level of correlation with extrinsic motivation (Abu-Hamour & Al-Hmouz, 2013).

The ARCS Model points to confidence as a condition for student motivation. If students believe in their chances to succeed, they become more motivated and follow through with actual success. Yurt (2015) stated that "expectancy-related beliefs were the most effective variable on mathematics performance" (p. 295). Satisfaction is also a condition for student motivation. Students who are satisfied with mathematics find enjoyment in what they are doing. When satisfaction comes from within or a positive classroom affect, students have a good attitude towards mathematics (Jiang et al., 2018). Achievement was linked to motivation and attitude (Mkhize, 2017). Motivation and achievement can have a reciprocal relationship as well (Hornstra et al., 2018; Mkhize, 2017). As students become more motivated, they achieve at a higher level. Then, their higher achievement leads them to be more motivated. Designing mathematics instruction so that students are able to feel success could have benefits on their motivation. Traditional mathematics instruction can divide mathematical concepts into more manageable portions for students (Magliaro et al., 2005), and more constructivist approaches like problem-based learning can allow students to succeed without the typical rote memorization of traditional mathematics (Choi, Lee, & Kim, 2019).

Lack of Motivation

Motivation in high school mathematics classrooms is declining across the United States. The majority of students do not even claim to like math (Cunningham et al., 2015) and many are not completing Algebra 2 (Stoker et al., 2018). Matthews (2017) points out that it is particularly upsetting to see learners that do not see relevance and value in mathematics. Corso et al. (2013) concluded that 60% of high school students are not motivated and engaged, and Baker and Robinson (2017) called it one of the most prominent problems currently facing secondary students.

Rekindling student motivation for math needs to be a priority for high school teachers. Skinner et al. (2008) emphasized that high school math classrooms were facing a serious problem with the lack of motivation. It is imperative for mathematics teachers to improve motivation in their classrooms. The benefits above provide enough impetus for teachers to increase motivation in their classrooms. Typically, younger learners begin with a lower level of motivation than adult learners (Morrison et al., 2013). Although, Ozkal (2019) pointed to a trend of decreasing motivation in the journey from primary school to high school. Others researchers pointed specifically to the transition from middle school to high school (Skinner et al., 2008). Jiang et al. (2018) stated that this decline in motivation was one of the primary reasons for conducting a motivation study with adolescent students, specifically referring to self-efficacy, task value, cost, and positive classroom affect as some of their measured constructs. There is a need for mathematics teachers to increase motivational support for their students (Nenthien & Loima, 2016). Mkhize (2017) claimed that decreasing motivation was a leading factor in lack of participation in mathematics.

Teacher perceptions of low motivation. Similar to research above, teachers believe that student achievement is affected by low motivation, even contributing to lower passing rates. Akers (2017) also remarked that low motivation in her math classes led to an 80% passing rate. Teachers attributed scores on performance tests and overall achievement to lack of motivation in mathematics (Amstelveen, 2019). It is becoming more difficult to make connections to students' lives so the relevance condition of the ARCS Model can be applied to increase student motivation. In mathematics, teachers are finding it more difficult to show students the relevance of mathematics (Mirza & Hussain, 2014). Students' motivation to complete work that does not seem significant to their lives is noticeably low (Jiang et al., 2018; Keller, 1987). Attard (2012) states that lack of student motivation and engagement is a central discussion among teachers. Teachers perceive students as unmotivated, lazy, and lacking a good attitude towards mathematics (Mkhize, 2017).

Effects of low motivation. Math classrooms lack active participation and enjoyment by students. Mirza and Hussain (2014) commented that math classrooms appeared dead to observers. As Ozkal (2019) stated, engagement was an outward display of motivation. Skinner et al. (2008) observe that "when children have lost their emotional enjoyment and interest in learning, they are not able to sustain behavioral participation in academic activities over time" (p. 777).

Additionally, there are other significant effects of low motivation. Lower levels of motivation, whether intrinsic or extrinsic, correlated to lower academic achievement (Nenthien & Loima, 2016). Students do not perform as well when they lack motivation in their classes (Baker & Robinson, 2017). Baker and Robinson (2017) indicated that secondary students lacked the motivation to simply complete assignments. Not only are students underperforming academically, some are not even making any effort. These effects of low motivation could also be connected to the characteristics of motivated students discussed previously. Motivated students display the characteristics of self-regulated learning strategies. Students are displaying lower ability to self-regulate learning, and academic achievement is suffering (Abu-Hamour & Al-Hmouz, 2013).

Studying Motivation

Motivation is a metaphysical concept that involves numerous internal and external forces within students. Due to the nature of motivation, the primary method of measuring motivation is through self-reporting surveys utilizing Likert scales for a variety of belief statements. Example studies included, but are not limited to studies by Jiang et al. (2018), Karakis, Karamete, and Okçu (2016), Patrick et al. (2007), and Yurt (2015). Students were typically given surveys that inquired about different dimensions of their motivation. Yurt (2015) used a questionnaire that measured task value statements and expectancy statements on Likert scales. Results were compared to another variable related to academic achievement. Correlation data was calculated with statistical tests (Yurt, 2015). Patrick et al. (2007) also utilized Likert scale measures of external forces that affected motivation, such as positive classroom perceptions and teacher support. Jiang et al. (2018) examined multiple motivation constructs by using portions of previous surveys to form their own. Karakis et al. (2016) also gave precedence for measuring motivation of students before and after some type of intervention.

Additionally, motivation survey quantitative data was enhanced by qualitative methods. Ghufron and Ermawati (2018) and Matthews (2017) utilized observations and interviews to provide more data alongside assessments. Cetin et al. (2019) also employed student interviews while students were participating in technology-enhanced problem-based learning activities. The mixture of quantitative data and qualitative data aligned with the research methods in each of the studies mentioned. Research questions drove the methods for studies (Morgan, 2014). Researchers were able to give more complete descriptions of variables under study as well (Schoonenboom & Johnson, 2017).

Traditional Mathematics Instruction

This section provides a brief overview of traditional mathematics instruction. It begins with an examination of basic differences between lecture and direct instruction, and how mathematics has typically used one of these formats. Also, the primary roles of teachers and students under these instructional methods are discussed. Then, I consider the general problems with traditional mathematics instruction and how it also relates to motivation.

Characteristics of Traditional Mathematics Instruction

Lecture or direct instruction. Traditional mathematics instruction is teacher-centered with the focus primarily on disseminating information from teacher to student. The teacher is the expert, and the student is the novice. Ornstein and Hunkins (2017) labeled this type of instruction as either lecture or direct instruction. Contrary to the belief of some, lecture and direct instruction are two different instructional approaches (Magliaro et al., 2005). Lecture is primarily the delivery of content from the teacher to the student through spoken word, written words, or a combination of the two. There is very little interaction between student and teacher. Direct instruction includes the following: modeling of content, processes, and skills; practice in applying concepts, processes, and skills; and on-going assessment and feedback (Magliaro et al., 2005). While there is more interaction between student and teacher, direct instruction is still teacher-centered.

Teaching mathematics in the lecture or direct instruction format does have the benefit of breaking math into manageable parts and allowing students to practice necessary skills for higher levels of problems (Magliaro et al., 2005). Le Roux (2008) states that "traditionally, mathematics has been presented as neutral and culture-free and as a silent, individual activity that involves completing procedures and solving traditional word problems" (p.307). The issue arises when the rigidity of this style inhibits creativity and problem-solving skills which are required in the real-world (Markušić & Sabljić, 2019). Teachers become engrossed in the drive to increase performance scores on standardized or non-standardized tests by focusing on forcing information onto students

(Baker & Robinson, 2017). Lecture and direct instruction are suitable for facilitating this type of lesson structure.

Role of the teacher. Instruction is centered on the teacher delivering content, processes, and skills. Traditionally, math has focused on instruction that is driven by the teacher versus the students (Amstelveen, 2019). Most teachers, even at the college level, teach using lecture or direct instruction (Meredith, 2015). Math content and delivery mode can be script-like in nature, as many math curriculums are uniform across the country (Galbraith, 2012). The teacher is more active than the students. During direct instruction, students do receive more time to apply the skills they are learning and be given feedback (Magliaro et al., 2005). However, teachers are still the prime deliverer of content and feedback. In summation, teachers are doing most of the work (Markušić & Sabljić, 2019). Thus, students are not actively engaged in the learning process. Teachers can transform classrooms through more constructivist instructional approaches (Schunk, 2016).

Role of the student. As Le Roux (2008) mentions, mathematics is primarily viewed as a quiet, individual activity. Students receive information, learn processes, and try to apply skills on preconfigured, similarly structured, word problems. Students work individually and focus on rote-memorization of facts and skills. Amstelveen (2019) examined the difference between traditional math classrooms and flipped math classrooms, and noted that students sat quietly and took notes in the traditional classroom. However, students were more actively engaged in the flipped classroom (Amstelveen, 2019). Students are passively receiving content in traditional classrooms. Freedom and innovation are discouraged (Markušić & Sabljić, 2019). This style can create boredom and a tediousness to math courses, which does not access the condition of attention from the ARCS Model (Keller, 1987; Meredith, 2015). Transitioning to more student-centered and active learning designs creates different classroom experiences for students (Tendhar et al., 2019).

Disadvantages of Learning Through Lecture or Direct Instruction

Lecture or direct instruction leads to a lack of interaction between students, negating the positive comprehension effects of cooperative learning (Wingard, 2018). Learning through direct instruction often places student practice in the home environment and limits an instructor's ability to provide timely feedback. Amstelveen (2019) echoed this sentiment and examined transformed classrooms through flipped instruction. The increase in student interactions with each other and the teacher led to more prompt feedback (Amstelveen, 2019). For example, students were able to receive immediate feedback on practice problems during class when their instruction was flipped (Amstelveen, 2019). While lecture and direct instruction are not equivalent, student perceptions may be the same. In her discussion on engagement in mathematics, Attard (2012) quoted students that were tired of listening to teachers constantly talking about what they were learning and instead wanted to be active.

Some researchers noted that instructional changes can be made to combat against disengagement associated with traditional instruction. Teachers responded to a survey that they noticed a huge difference in student activity when doing problem-based learning versus direct instruction, and that students were not as motivated or interested during direct instruction (Markušić & Sabljić, 2019). Amstelveen (2019) observed that students were more engaged during flipped instruction versus traditional instruction. Students were more responsible for their own learning (Amstelveen, 2019). More lively discussion about content and application can take place when the students have the lesson at home, then come together in class. While large scale changes to instruction can affect student motivation to engage in learning, simple real-world connections, positive learning environments, and student choice in learning can also provide conditions for motivation (Akers, 2017).

Rote Memorization Versus Problem-Solving Skills

In addition to disengaged students, teachers' focus in many math classrooms is on memorizing concepts and processes. Even applications in the form of word problems were contrived uses of processes in comparison to actually solving an ill-structured real-world example (Matthews, 2017). Higher-level thinking skills are absent. Math teachers were inclined to contrive a problem that utilizes current math topics versus students solving open-ended problems that required students to figure out what math to use and how to apply it (Galbraith, 2012). Proponents of problem-based learning pointed to its use to combat rote memorization (Choi et al., 2019). Problem-based learning will be discussed in more detail later, but it is a more student-centered approach that focuses on problem-solving skills not present in lecture or direct instruction (Choi et al., 2019). Mirza and Hussain (2014) stated that the best math teachers have always encouraged their students to learn beyond rote memorization.

Traditional mathematics is primarily a teacher-centered affair, which leads to a lack of student ownership in learning and an excessive amount of emphasis on rote memorization. Problem-solving skills are ignored or severely lacking. Teachers play an important role in designing instruction that transforms traditional mathematics classrooms (Baker & Robinson, 2017; Le Roux, 2008). Low student motivation does not just originate with students. Teachers' roles are creating classroom environments that have elements from the ARCS Model conceptual framework to support motivation (Baker & Robinson, 2017).

Problem-Based Learning

One major concern in traditional mathematics classrooms is the teachers are doing all the work (Markušić & Sabljić, 2019). Therefore, as teachers do most of the work, students become bored and unmotivated to learn. The search for a more student-centered approach will inevitably encounter constructivist thought. Constructivist theory suggests that students construct their own knowledge through experiences of problem-solving and higher-level thought processes (Schunk, 2016). The teacher becomes more of an expert guide who stimulates critical thinking through questioning (Choi et al., 2019; Mirza & Hussain, 2014). Learning is a more student-centered approach. Students make decisions and construct meaning about central tasks or problems. Merrill (2002) emphasizes the claim that the problem should be ill-structured, and students will learn the content needed to solve the problem on their own. Often, students will even construct their own methods in mathematics. My search turned to constructivist methods that math teachers were using to affect students' motivation, and problem-based learning was the approach I elected to use for my action research. This discussion on problem-based learning is divided into the following sections: (a) defining problem-based learning, (b) structure of problem-based learning in classrooms, (c) problem-based learning in mathematics classrooms, (d) teacher and student perceptions of problem-based learning, (e) deficiencies of problem-based learning in classrooms, (f) problem-based learning in research, and (g) summary of problem-based learning effects in classrooms.

Defining Problem-Based Learning

Problem-based learning originated in a Canadian medical school where students were given the task of solving problems within context that had multiple solutions (Ghufron & Ermawati, 2018). Barrows and Tamblyn (1980) stated that their introduction of problem-based learning evolved from the need for medical students to be able to apply their knowledge in clinical situations with patients. Students were allowed to construct their own knowledge through innovative solutions to patient neurological problems and reinforced the background knowledge of basic classes in medicine. Problem-based learning expanded to numerous disciplines since the 1960s (Ghufron & Ermawati, 2018).

Problem-based learning is intended to be open-ended, ill-structured, and more like models of real-world problem-solving (Ghufron & Ermawati, 2018; Le Roux, 2008; Savery, 2006). Because problem-based learning mimics the messiness of real-world problem solving, it provides opportunities for students to construct meaning outside of the context of normal classroom instruction. Barell (2007) states that students can interact with "complex, intriguing situations that foster inquiry, research, and the drawing of reasonable conclusions" (p. x). Teachers want content knowledge and skills to be applicable outside of the normal context of instruction, and they want students to be able to adapt, even if their current context does not match how they learned content in class (Soderstrom & Bjork, 2015). Problem-based learning helps students gain conveyable problem-solving skills that work in a variety of disciplines and situations (Fukuzawa et al., 2017). For this study, problem-based learning was defined as instruction facilitated by real-world scenarios with open-ended solutions or application of algebraic concepts.

Structure of Problem-Based Learning in Classrooms

Even though problem-based learning was less structured and primarily student led, parameters were developed in the form of a tutorial process (Barrows & Tamblyn, 1980; Hmelo-Silver, 2004). During the process, emphasis is placed on collaboration between students, facilitation by the instructor/tutor, reflection on knowledge learned, and action steps of problem solving (Barrows & Tamblyn, 1980; Hmelo-Silver, 2004). See Figure 2.1 below for a representation of the problem-based learning process. The process begins with the presentation of the problem. Hmelo-Silver (2013) stated that problems can support extensive learning but not cover every aspect of the specific course learning. Students begin to identify facts, preliminary hypotheses, and areas of further research. Barrows and Tamblyn (1980) recommended that students collaborate to increase ideas and learn socially. For the remainder of the process, the teacher acts as a tutor that guides students towards resources and elicits thoughts from students with questioning techniques (Barrows & Tamblyn, 1980). It is not their job to distribute knowledge.

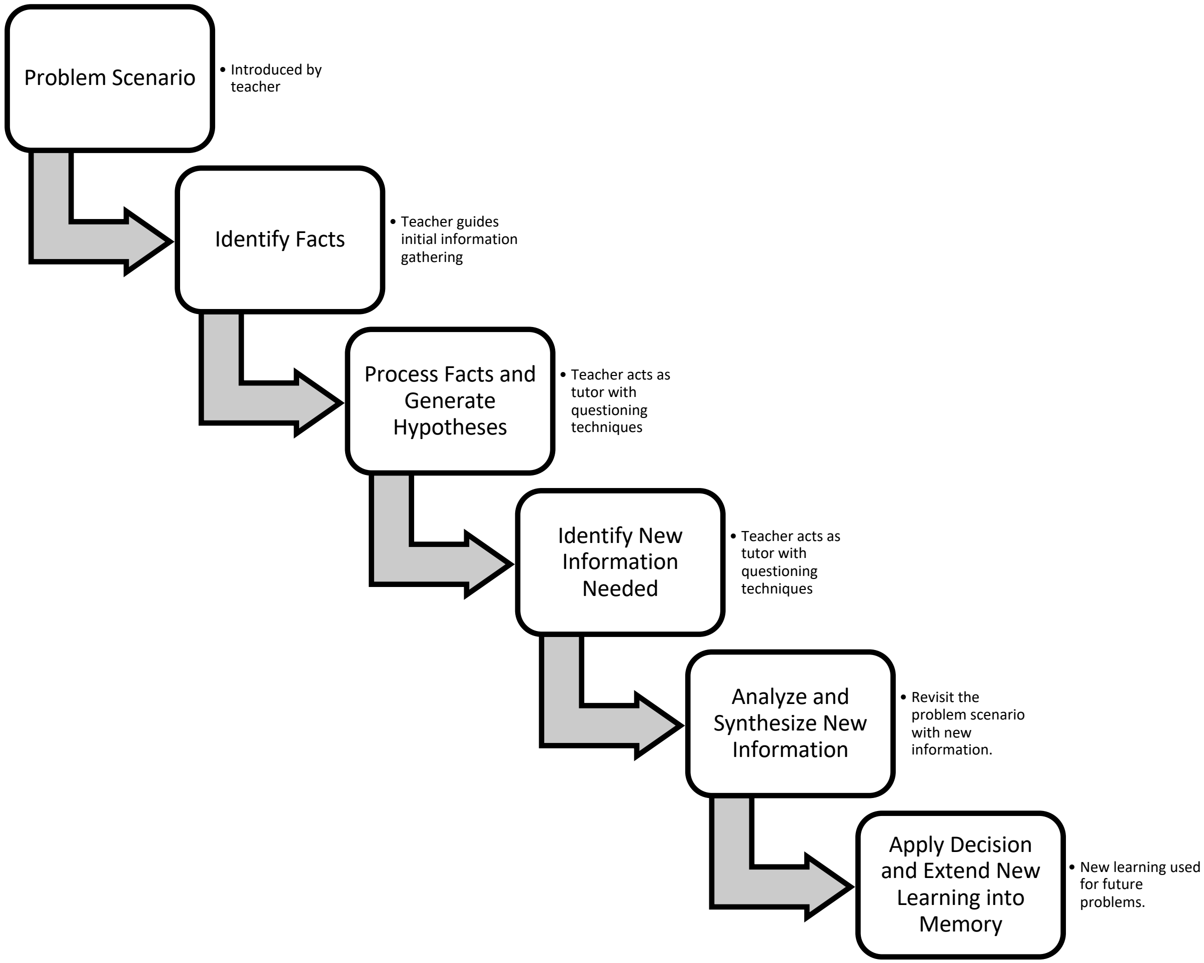


Figure 2.1 *The Problem-Based Learning Process.* Adapted from Barrows and Tamblyn (1980) and Hmelo-Silver (2004).

The teacher strives to make students think about alternatives and search for appropriate knowledge for the problem (Barrows & Tamblyn, 1980). Problem-based learning does not have to be content driven, but it can connect directly with curriculum concepts (Hmelo-Silver, 2013). The overall goal is for students to gain knowledge that has the flexibility to adapt to future problem solving demands (Barrows & Tamblyn, 1980; Hmelo-Silver, 2004, 2013). Although original studies were conducted in medical school contexts, the method was adapted by changing the problems (Barrows & Tamblyn, 1980).

Problem-Based Learning in Mathematics Classrooms

Students are pushed out of their comfort zone to solve ill-structured problems that mimic the real-world. Problem-based learning in mathematics is a radical shift away from traditional lecture or direct instruction (Markušić & Sabljić, 2019). As Galbraith (2012) emphasizes, real life can often be messy, and students must identify and apply high level mathematics. Teachers must move beyond the typical applications problems that are contrived to show students math application and move towards ill-structured examples that allow students to construct mathematical solutions on their own (Galbraith, 2012; Le Roux, 2008). For example, there is a substantial difference between showing students the dimensions of a geometric shape that create a quadratic equation for area and telling them to find out how wide their concrete can be around an in-ground pool if they only have a certain budget. Both involve quadratic thought processes, but the latter challenges students with the messiness of real-world problems versus rote memorization. Students are encouraged to utilize and further develop real-world mathematical skills that can apply later in their lives (Galbraith, 2012). Chua et al. (2016) state that students learn skills that have lifelong impacts on their approach to problems they encounter.

Connecting mathematics to real-world scenarios accesses conditions of the ARCS Model that affect student motivation. These real-world scenarios kept students' attention and even drove them to actually participate in mathematics (Akers, 2017; Meredith, 2015). Corso et al. (2013) showed that the real-world connection allowed students to see the relevance of mathematics to their lives, and relevance motivated students to learn (Keller, 1987). Teachers also accessed the satisfaction condition when they allowed students choice in how they constructed their knowledge (Akers, 2017). Teachers in mathematics also need to be aware that allowing students to work collaboratively could be a possible confounding variable that is increasing motivation (Mirza & Hussain, 2014).

Teacher and Student Perceptions of Problem-Based Learning

According to Markušić and Sabljić (2019), problem-based learning allowed teaching to be more "dynamic, accessible, and interesting" (p. 26). Barrows and Tamblyn (1980) noted that teachers and students both were impressed with problem-based learning's effects on motivation and learning. When interviewed about problem-based learning, teachers stated that students displayed more motivation, self-confidence, responsibility, and problem-solving skills during problem-based learning (Ghufron & Ermawati, 2018). Students gave some of the same perceptions about their experience with problem-based learning, and some even claimed to love learning (Ghufron & Ermawati, 2018). Meredith (2015) stated that "faculty members and students considered problem-based learning as a tool to improve student motivation, critical thinking, and overall learning" (p. 47). Thus, problem-based learning is an instructional design tool that teachers can use to affect change in perceptions of lessons.

Deficiencies of Problem-Based Learning in Classrooms

PBL can be very difficult to implement, because teachers need more time and good management skills (Ghufron & Ermawati, 2018). According to students, teachers need to provide clear instruction to combat against confusion about what is expected during the problem-based learning process (Ghufron & Ermawati, 2018). Problem-based learning is more student-centered, and students must lead the process. They must be more active participants (Meredith, 2015). If motivation is already low, it could be a potential hurdle for students and teachers to implement problem-based learning. Finding the right problems that are ill-structured and promote mathematical understanding versus just contriving an application of an equation is a challenge (Galbraith, 2012; Le Roux, 2008). Assessing problem-based learning requires evaluations that examine their problem solving processes, ability to reason, and ability to provide resolutions backed by researched knowledge (Barrows & Tamblyn, 1980). Barrows and Tamblyn (1980) also pointed out that the problem-based learning method did not translate well to assessments that only tested recall and short processes.

Problem-Based Learning in Research

Research on problem-based learning involved implementation in individual classrooms or entire departments within schools. Studies included, but are not limited to, research examined below. Fukuzawa et al. (2017), Ghufron and Ermawati (2018), and Markušić and Sabljić (2019) employed surveys or questionnaires to measure a variety of constructs surrounding problem-based learning. Markušić and Sabljić (2019) focused on teachers' experiences with problem-based learning and their thoughts on achieving learning outcomes. Fukuzawa et al. (2017) provided questionnaires with Likert scale scoring on topics such as motivation, learning course outcomes, and technology usage with problem-based learning. Although questionnaires provided ample data, Hmelo-Silver (2012) contended that these types of studies on problem-based learning could be enriched by the addition of observational data.

In addition to their questionnaire, Ghufron and Ermawati (2018) collected data through in-depth interviews and observations. Their intention was to utilize qualitative data to provide richer descriptions of strengths and weaknesses of problem-based learning. Cetin et al. (2019) implemented technology-enhanced problem-based learning activities with a treatment group in an experimental study. Students were interviewed to obtain qualitative data about their attitudes towards problem-based learning and mathematics. Meredith (2015) also used interviews to collect data from students and teachers after implementation of a problem-based learning intervention. Meredith (2015) examined perceptions of changes in students' motivation as well as students' achievement. Applying mixed methods approaches provided more information for a more complete picture.

Summary of problem-based learning effects in classrooms. Employing problem-based learning gives mathematics teachers a tool to transform their instruction away from traditional mathematics instruction. Using real-world problems promotes learning when new knowledge is gained and applied (Merrill, 2002). Students' creativity and problem-solving skills that transfer to multiple content areas increase as they construct their own methods to solve these ill-structured problems (Markušić & Sabljić, 2019). Mirza and Hussain (2014) used what they coined as rich tasks to increase motivation to learn, and it also afforded them gains in collaboration and differentiation. Fukuzawa et al. (2017) and Baker and Robinson (2017) both saw a significant difference in motivation through the use of problem-based learning versus direct instruction.

However, Fukuzawa et al. (2017) noted that some students felt they were not actually learning the course material. Due to the nature of problem-based learning requiring independent research, students felt that they were not being given instruction on how to solve the problem (Fukuzawa et al., 2017). Students noticed the benefit of the learning process and collaboration, but they still desired presentations on subject matter (Fukuzawa et al., 2017). Teachers also noted the lack of class time that was available to use problem-based learning and still cover subject standards (Markušić & Sabljić, 2019). In their study, Markušić and Sabljić (2019) noted the short amount of time to be able to introduce literary terms that students needed to further their abilities to analyze problems during the problem-based learning portion of their classes. Hmelo-Silver (2012) stated that some studies also gave teachers freedom to offer lectures or direct instruction alongside problem-based learning.

Technology-Enhanced Lessons

The field of educational technology entails the creation and management of technological methods and resources to improve student learning (AECT Definition and Terminology Committee, 2004; Januszewski & Molenda, 2016). Even though many teachers may not create the actual technology that they use in their classrooms, they are responsible for managing its use. Sound instructional design is still the framework through which technology usage is filtered (Morrison et al., 2013). Technology enhancement provides opportunities for students to utilize technology within the learning process, but it is not the sole source of learning. One caveat was echoed in the research: Teachers needed time to learn technology and specific training on how its integrated into their subject (Fry, 2015; Kalonde, 2017b). Emphasis still needed to be based on pedagogy and content driving the technology, not the opposite (Hilton, 2016; O'Byrne & Pytash, 2015). Zheng, Warschauer, Lin, and Chang (2016) found that pedagogy still took precedence over technology in determining the success of technology integration. Methods that teachers used to introduce concepts, processes, and skills were more important than materials (Zheng et al., 2016).

Therefore, teachers can use technology to enhance presentations even in direct instruction, but Ghosh (2017) calls teachers to utilize technology as an aid for explorations of mathematical concepts and real-world situations. Teachers can move beyond a simple electronic version of notes on the board and allow students to interact with technology. For example, students can use the online calculator Desmos to explore differences between mathematical functions. Students can also utilize the internet to research data related to problem-solving within business examples. Often, teachers and parents feared the pervasiveness of technology due to its negative connotations, but communication and interaction with the surrounding world was invaluable (Fry, 2015; Kalonde, 2017b). Primarily, students used technology for research and increased productivity (Kalonde, 2017b). In math classrooms, teachers can ask students to examine a topic before class begins or allow students the technology aid of calculators. Tools, like the online calculator Desmos, provide more opportunities for students' interaction with content and technology. Students can see and experience math content concurrently.

Technology-enhanced lessons take on many forms. Cetin et al. (2019) used technology that allowed students to explore functional relationships in mathematics without the need for an actual equation. One-to-one laptop programs allowed students to communicate in nontraditional ways, research beyond the confines of classrooms or textbooks, and experience teaching in different formats (Zheng et al., 2016). For this study, technology-enhanced lessons were defined as lessons that utilized technology to support traditional instruction, lessons that allowed students to use technology for assistance in their explorations, or lessons that used technology to improve interaction with content and class members. In easier terms, technology enhanced lessons for this study were lessons that used technology as an aid, not the sole source of learning. The following sections examine (a) benefits of enhancing lessons with technology and (b) student perceptions of technology in lessons.

Benefits of Enhancing Lessons with Technology

Utilizing technology within lesson structure provides opportunities for students to move beyond classroom walls. Students are not limited to the teacher and textbook, as is usually the case with lecture or direct instruction (Kalonde, 2017a). Fry (2015) stated that different forms of technological media allowed students to learn from others around the world and communicate with each other in different ways such as blogs, online message boards, and social media. More timid students gain the ability to have their voice heard, even if they do not normally talk during class. Students who typically retreat into the background when presenting content vocally can create exciting and engaging multimedia presentations. Zheng et al. (2016) noted that instead of inhibiting communication as some feared, one-to-one laptop environments actually increased communication between teachers and students. Teachers can provide feedback quickly on technology-enhanced assignments. Students can display their knowledge above and beyond traditional pencil and paper tests. When students are formulating answers and arguments on discussion boards, they are accessing higher levels of thinking (Ornstein & Hunkins, 2017).

In a meta-analysis by Zheng et al. (2016), other benefits of technology-enhanced lessons included an increase in academic achievement, enhanced organizational techniques, and more student autonomy in lessons. Teachers can step back and allow students more freedom and interaction. Students can be asked to share a video of their career interests and then make connections between careers and mathematics. Then, their classmates can evaluate their presentation and strength of connections. Students can also be allowed to choose their own path to knowledge with techniques that combine technology and problem-based learning (Cetin et al., 2019). Lessons are not limited to a certain time and place, and students can direct the paths of their learning (Kalonde, 2017b).

Furthermore, Ghosh (2017) pointed out that computer algebra systems were revolutionizing mathematics. Students were no longer limited by learning mathematical methods followed by examples that only applied to that specific content (Ghosh, 2017). They were allowed to explore topics that go beyond their current levels as problems require instead of their current levels dictating the problems (Ghosh, 2017; Matthews, 2017). Students are moving beyond the rote memorization of lecture and direct instruction. Ghosh (2017) states that students are focusing on "exploring, conjecturing, reasoning and problem solving" (p. 1). For example, students can use technology such as

Geogebra to automate calculations and geometric processes to test their theories about shapes and measures. The automation provides quicker answers and feedback which allows students more time for exploration.

Additionally, the benefit that connects directly with this study is the possibility to increase motivation. Harper and Milman (2016) noted the theme of increased student motivation in their meta-analysis of studies with one-to-one technology integration in schools. The uses of technology may differ from study to study, but students' attitudes toward lessons can be affected by technology enhancement of lessons. Students found the use of technology more interesting than traditional pencil and paper work (Zheng et al., 2016). When answers were obtained with technology-enhancement, students experienced less frustration with tedious mathematical processes (Cetin et al., 2019). Zheng et al. (2016) indicated that "a number of studies report higher student engagement, motivation, and persistence in one-to-one laptop environments than in non-laptop or shared laptop classrooms" (p. 1071). Therefore, integrating technology usage for all students holds potential benefits for increasing student motivation.

Student Perceptions of Technology in Lessons

Students enjoy using technology beyond pencil and paper. Attard (2012) gave an example of students utilizing technology to design a dream home floor plan, and they enjoyed the project even though math was involved. Ghosh (2017) pointed out that students even found beauty in higher levels of mathematics when they used a computer program. For example, students used a program called Mathematica to make several levels of calculation in Newtonian Calculus concepts, but they were still able to find beauty in connections to fractals (Ghosh, 2017). Allowing students to explore mathematics, instead of just telling them about it, creates a more positive attitudes towards mathematics. Allowing students the chance to use technology that is already so widespread in their lives makes school work more interesting (Zheng et al., 2016). Technology integration takes on many forms, but benefits are evident.

Flipped Classroom

As discussed previously, traditional instruction primarily places teacher-centered delivery of content in the classroom and student practice at home (Amstelveen, 2019; Magliaro et al., 2005). Some teachers are choosing to completely turn this scenario around, thus the term: *the Flipped Classroom*. According to Eppard and Rochdi (2017), there is an increasing body of research on its use in STEM classrooms. Amstelveen (2019) defined flipped classrooms as those where students studied lessons through video or other media at home, then classwork and practice during actual seat time with instructors. Meredith (2015) included the simple act of reading content at home before class as a flipped classroom example. The premise of flipping the classroom occurred before the term was coined whenever teachers placed educational events that typically happened within the classroom at home and vice versa (Eppard & Rochdi, 2017). There is not a substantial argument about defining flipped classrooms, although the term itself originates with science teachers using video lessons at home and projects in class (Eppard & Rochdi, 2017). For this study, the definition of the flipped classroom was lessons occurring through video at home followed by practice or application in class (Amstelveen, 2019; Eppard & Rochdi, 2017).

Benefits of a flipped classroom. In the early stages, flipped learning used simple media. Book readings were assigned and discussed during class. Students now have access to an ever increasing variety of media for flipped learning, and teachers can take advantage of this situation by allowing students to learn in their current world (Eppard & Rochdi, 2017; Tulodziecki & Grafe, 2012). For example, students have access to up-to-date classroom content information on different technological media that are available (Fry, 2015; Tulodziecki & Grafe, 2012). Learning can occur without constraints of time and location. Students can watch video lessons at home, or at coffee shops. When students return to school, flipped learning provides more time for teachers to assist students and plan enrichment activities (Amstelveen, 2019). Students can practice content from the flipped lesson or higher levels of real-world application problems. At this point, teachers can provide more timely feedback. The extra level of teacher support helps build student confidence which supports higher student motivation (Nenthien & Loima, 2016). Higher level cognitive work and student-centered activities can also take place in the expanded classroom time. Eppard and Rochdi (2017) also pointed out that flipped learning facilitated differentiated learning for all students. Teachers can provide more individualized instruction and feedback during each class.

Student perceptions of flipped classrooms. Eppard and Rochdi (2017) stated that there were mixed results from numerous studies, but most claimed that students had an overall positive experience with flipped learning. Some students believed that they learned better through flipped video lessons (Amstelveen, 2019). Amstelveen (2019) questioned whether flipped lessons led students to be more motivated to learn. Students who prefer one style of instruction over another do not necessarily become more motivated to learn (Yu & Singh, 2018). Yu and Singh (2018) noted that different styles of instruction did not display significant effects on two motivational constructs of self-efficacy and interest in mathematics. However, Gaughan (2014) stated that her students were more engaged with course material which signified they were motivated to learn. Students during the action research by Gaughan (2014) made comments that they were glad to know more background to the lesson before in-class activities. They were also more in tune with how their teacher was thinking (Gaughan, 2014). Students are then able to ask more applicable questions and receive direct assistance with their most important areas of need.

Deficiencies of a flipped classroom. Initial excitement about new forms of instruction can dissipate because of similarities to direct instruction (Meredith, 2015). In the beginning, students can be attracted to the novelty of learning through different instructional designs. If delivery style remains the same at home, students eventually realize it is just a different way to package direct instruction or lecture. Balancing forms of instruction is essential. Some saw increased time on media consumption as a potential problem (Tulodziecki & Grafe, 2012). Fry (2015) declared that media should not be demonized. Just as balancing instructional design is key, so is balancing time spent on media. Amstelveen (2019) pointed out that flipping a classroom was possibly more suitable for a more homogenous group of participants. Differing levels of students, such as doing research on honors students versus college preparatory students, could produce very different results during research. Student participation differences stand out as well. Gaughan (2014) experienced issues in her action research with knowing whether or not a student had watched her lesson videos at home.

Although it is not really a deficiency, the time required by teachers to plan for an effective flipped classroom can hinder full-scale implementation. Essentially, teachers are planning two lessons. Gaughan (2014) mentioned the large amount of time that she spent on making video lessons, and she still had to have engaging lessons prepared for the in-class session. Eppard and Rochdi (2017) believe that it goes even deeper with teachers planning to access multiple learning theories and how they overlay with Bloom's taxonomy. It comes as no surprise that Meredith (2015) noticed very few teachers maintained a flipped classroom on a permanent basis during her study.

Research on flipped classroom instruction. Eppard and Rochdi (2017) stated most research on flipped classrooms dealt with qualitative data about students' and teachers' perceptions. A few studies examined quantitative data of achievement and if it was significantly different from achievement during traditional instruction (Eppard & Rochdi, 2017). Gaughan (2014) implemented the flipped classroom as an intervention in world history classes with the primary goal of obtaining more class time devoted to understanding reading sections that were given at home. Gaughan (2014) created a survey to measure qualitative data about student perceptions and self-reporting of success with course content. Amstelveen (2019) implemented a flipped classroom in college Algebra courses, which were similar to high school Algebra 2 content, processes, and skills. Amstelveen (2019) also utilized a survey on a five-point Likert scale and the final exam for the Algebra course. Questions on the survey asked students about experiences during flipped learning, course materials, and the instructor (Amstelveen, 2019).

Blended Learning

During instruction, teachers can find a balance between problem-based learning, technology enhanced lessons, flipped lessons, lecture, and direct instruction. This type of instructional design is given the moniker of hybrid learning or blended learning (O'Byrne

& Pytash, 2015; Simonson et al., 2014). The blending of instruction allows teachers to mix a variety of methods for delivering content. Teachers can utilize a mix of face-to-face and computer-mediated instruction (O'Byrne & Pytash, 2015). Some researchers pointed to teachers still providing flipped or web-based lessons accompanied by short lectures or direct instruction in class (Amstelveen, 2019; Magliaro et al., 2005).

Flipping lessons can also provide teachers time to utilize problem-based learning. Cetin et al. (2019) utilized what they called technology-enhanced problem-based learning activities. Students were given central problems that encouraged them to manipulate mathematical functions through use of technology tools like Geogebra (Cetin et al., 2019). Students discovered relationships between functions and their graphical representations (Cetin et al., 2019). Tulodziecki and Grafe (2012) emphasize that utilizing different forms of media is essential for students. The world in which students live contains a variety of media presentations, and they should experience learning from and presenting with the different forms of media (Tulodziecki & Grafe, 2012). Offering multiple forms of instruction affords teachers opportunities to gain various benefits of each type of instruction.

Benefits of blended learning. Many benefits of utilizing blended instructional approaches are covered in the individual benefits for each type of instruction. Teachers can still use traditional instruction to teach the critical mathematical skills that are needed for problem solving (Magliaro et al., 2005). Then, teachers can utilize flipped lessons to offer some instruction at home followed by a variety of methods during in-class portions (Amstelveen, 2019). Teachers can offer extra practice and give feedback that increases students' knowledge and confidence in mathematics (Nenthien & Loima, 2016). Increase in confidence supports student motivation (Keller, 1987). Class time can also be utilized to offer problem-based learning giving students real-world problem-solving skills (Ghufron & Ermawati, 2018; Markušić & Sabljić, 2019; Meredith, 2015). Students move beyond the rote memorization of typical mathematics instruction. Class becomes more interesting, and students gain motivation through the four conditions of the ARCS Model (Keller, 1987). Blending learning allows teachers to reach students who enjoy each type of instruction. Teachers can employ different levels of face-to-face and technology-mediated instruction to pique student interest, provide new avenues for expression, and motivate students to learn. Problem-based learning also offers an instructional change that can be made in conjunction with technology-mediated instruction. Classrooms transition to a more student-centered approach.

Chapter Summary

Motivation is the driving force that encourages students to start and complete tasks, even in the most difficult scenarios (Dimitroff et al., 2018; Nenthien & Loima, 2016; Yurt, 2015). The benefits of students who are behaviorally, emotionally, and cognitively involved in class provide an overwhelming impetus for increasing motivation in mathematics classrooms (Fredricks & McColskey, 2012). Student achievement and preparation for life outside of school are directly related (Hwang, 2016; Ozkal, 2019). Teachers can affect motivation within their classrooms by their instructional design and environment. Traditionally, mathematics classrooms have been dull, almost mechanical studies of processes (Le Roux, 2008; Magliaro et al., 2005). Rote memorization of concepts, processes, and skills are the norm (Markušić & Sabljić, 2019). Problem-based learning provides teachers with instructional techniques that encourage problem-solving and active student participation (Barrows & Tamblyn, 1980; Hmelo-Silver, 2004). It is also a radical shift from traditional instruction that allows students to make decisions about their own learning process (Markušić & Sabljić, 2019). Changing instructional design could potentially have effects on motivation within mathematics classrooms (Ghufron & Ermawati, 2018).

Technology-enhanced lessons also modify instruction for students. Ghosh (2017) states that mathematics teachers can utilize technology to allow students to explore complex mathematical concepts in a shorter amount of time. Teachers can also experiment with flipping instruction at home and practice in class (Amstelveen, 2019). Combining different forms of instruction such as direct instruction, problem-based learning, and flipped lessons is known as blended learning (O'Byrne & Pytash, 2015). Problem-based learning infused with technology provides opportunities for students to learn problem-solving skills and mathematics in real-world contexts. It also provides teachers opportunities to change how their students view mathematics and motivate them to truly want to learn mathematics.

CHAPTER 3

METHOD

The purpose of this action research was examining problem-based learning in a flipped classroom instructional environment and measuring its effect on students' motivation and achievement in Algebra 2 at Pali High School. This study addressed the following research questions: 1) What is the impact of problem-based learning in a flipped classroom instructional environment on students' motivation in mathematics?; 2) What is the impact of problem-based learning in a flipped classroom instructional environment on students' self-efficacy in mathematics?; 3) What is the impact of problem-based learning in a flipped classroom instructional environment on students' mathematics achievement on Systems of Equations and Quadratic Functions?; and 4) What are students' perceptions of problem-based learning in a flipped classroom instructional environment?

Research Design

The purpose of this action research was examining problem-based learning in a flipped classroom instructional environment and measuring its effect on students' motivation and achievement in Algebra 2 at Pali High School. Action research was selected, because I implemented an innovation in my Algebra 2 class and examined its effects in abundant detail. Greenwood and Levin (2007) claim action research is a rigorous research strategy that has greater similarity to real scientific inquiry. Direct action is taken in a local context to enact change, and data collection and analysis is understood as being rife with complexity (Greenwood & Levin, 2007). Findings lead to strong reflection and continuous cycles of improvement (Rudestam & Newton, 2007).

As researcher, and teacher, I actively made changes in my classroom instruction and tested the results (Johnson & Christensen, 2017). As Belzer and Ryan (2013) pointed out, action research on problems of practice test direct results of interventions, but results are not intended to make generalizations to theories or larger populations. Mertler (2019) also stated that action research is used to measure effects of interventions in researchers' local settings. Truth about effects on local samples are obtained and degrees of significance are determined, even if generalizations are not made. While generalizations cannot be made, knowledge is discovered that is applicable in local settings and particular researcher's own practice (Rudestam & Newton, 2007).

Traditional research and action research both follow a systematic inquiry process. The major difference is traditional research is applied to find and analyze theories that can be generalized to the population at large. Action research, on the other hand, is utilized to address problems of local concern (Rudestam & Newton, 2007). Often, the researcher is directly involved in the entire process and takes action directly with the participants (Greenwood & Levin, 2007; Herr & Anderson, 2005). Kinash (2006) states that action research "enables the researcher to effect change simultaneously while collecting and interpreting data" (p. 5). Findings are used to improve the local conditions for researcher and participants. My research was implementing problem-based learning in a flipped classroom instructional environment to examine effects on students' motivation in mathematics. My students were directly affected by my intervention. Even though I used data collection instruments for pretest and posttest, my quasi-experimental setup was not setup as traditional research experiments including treatment and control groups.

Connected directly to my decision to utilize action research was my choice to implement a mixed methods approach. Mertler (2019) stated that "action research studies tend to align better with mixed-methods designs" (p. 106). Mixed methods research involves both quantitative and qualitative data sources as well as different analysis methods. Morgan (2014) states that researchers using mixed methods must use quantitative and qualitative methods in their unique aspects, but also must be able to integrate both methods effectively. Mixed methods research is an approach that is used to compensate for weaknesses, and exploit strengths of quantitative and qualitative methods (Shenton, 2004). Creswell and Creswell (2018) stated that "more insight into a problem is to be gained from mixing or integration of the quantitative and qualitative data" (p. 213).

Moving beyond the argument of compensation for strengths and weaknesses of each method, it was critical to make sure that the methods aligned with the purpose of the research (Morgan, 2014). My first three research questions dealt with the significance of change in student motivations and achievement, and led to quantitative data being a primary driver of my research design. However, I also wanted to examine perceptions of my students and myself during the intervention. Qualitative data allowed me to understand perceptions through feelings and experiences of those directly involved (Morgan, 2014; Rudestam & Newton, 2007; Tracy, 2020). Quantitative and qualitative data were mixed to create a more complete picture of the local context and effects of the intervention (Schoonenboom & Johnson, 2017). Greenwood and Levin (2007) also stated that mixed methods aligned better with the true multidimensionality of life.

Researchers outlined what they call a convergent design method, or a focus on triangulation (Creswell & Creswell, 2018; Mertler, 2019; Schoonenboom & Johnson, 2017). The premise behind this design was to collect quantitative and qualitative data at approximately the same time to build a more complete picture of research (Creswell & Creswell, 2018; Mertler, 2019; Schoonenboom & Johnson, 2017). During my research, convergent design methods were applied by obtaining qualitative information about participants' experiences during the quasi-experimental innovation. Interviews helped me gain a deeper understanding of participants' experiences with problem-based learning in a flipped classroom instructional environment. I asked students about their beliefs towards mathematics during the experimental phase of my research. I used interviews to ask students about changes in their motivation toward mathematics. I also made observations of students' behavior and attitudes. My students also responded to journal prompts about experiences during problem-based learning in a flipped classroom.

Additionally, I obtained quantitative data. Sources for quantitative data were scores on a student motivation survey and a performance test for particular mathematical functions. The setup for my quantitative portion of my research design was a One-Group Pretest-Posttest pre-experimental design (Creswell & Creswell, 2018). I assessed students' responses on the two measures before and after implementing problem-based learning in a flipped classroom instructional environment. Then, descriptive statistics and inferential statistics were used to explain findings without generalization (Adams & Lawrence, 2019; Rudestam & Newton, 2007).

Setting and Participants

This study took place in a Pali High School Algebra 2 classroom. Pali High School is located in a rural area in the southern United States. There were various socioeconomic backgrounds, but little diversity in cultural and racial backgrounds. Approximately 25% of the students were on free or reduced lunch. The majority of students were Caucasian with only 5% of students being Asian or African American. Pali was not a representative community for the nation at-large. As researchers note, generalizability to the population at large is not the goal of action research (Buss & Zambo, 2014; Herr & Anderson, 2005; Johnson & Christensen, 2017; Mertler, 2019).

The experimental design for this study was not a pure experiment. It was what Creswell and Creswell (2018) labeled a pre-experimental design. Therefore, students were not observed in a laboratory type setting. The majority of the research setting was in their normal math classroom with two exceptions. One exception from the norm was changing from rows of desks to grouped desks. Students participated in more collaborative work throughout the study, which necessitated more flexible seating arrangements. The second exception was during flipped portions of instruction. Students were responsible for accessing instruction at home or utilizing internet access after school.

Pali County School District operated under a one-to-one technology initiative. According to the technology resource teacher, Pali High School averaged around 93% of students with Chromebooks (personal communication, March 21, 2018) and Wi-Fi hotspots were also available. Students had Wi-Fi access during school, and times were offered outside of normal class time. They were also allowed to use graphing calculators provided by the school and mobile devices of their own.

The study involved 22 Algebra 2 College Preparatory students. Ten students were Sophomores, and 12 were Juniors. Sixteen students were female, and six were male. Only one student was non-Caucasian. This student was Hispanic. A random name generator was utilized to obtain student pseudonyms. Student pseudonyms from the focus group interview and quoted students from Chapter 4 are listed in Table 3.1 below. Students became members of my Algebra 2 class through the normal registration process. They were appointed to Algebra 2 through a variety of channels, primarily guidance and previous course performance. However, the registrar and administration historically has had some effect on the registration process.

Table 3.1 *Student Pseudonyms*

Focus Group Interview	**Other Quoted Participants**
Stefan Hari	Loren Paul
Miriam Fatema	Abraham Pyry
Antonia Teagan	Wally Vratislav
Lan Risto	Annie Bram
Alina Hadley	Kristiana Jeppe
Catherin Klyment	Yasmin Nabuko
	Marie Raju
	Bertrand Androkles
	Sarah Abbey
	Aleksandra Murali

Therefore, I was not responsible for, or involved in, selection of the sample for this study. It was purely a purposive convenience sample of students in my Algebra 2 class. The study did not represent all of the Algebra 2 students located at Pali High School. Students, or parents, who chose not to consent to being a part of the study, would have been excluded from data collection and analysis and only participated in lessons and activities. Fortunately, all 22 students and parents consented to participating in the full study.

Action Research Innovation

The innovation strategy used during this study was problem-based learning in a flipped classroom instructional environment. Ill-structured, real-world problems served as basis for problem-based learning. They were designed by the teacher, with the exception of one problem adapted from an example by Kaplinsky (2015). The flipped classroom model was utilized for the majority of Algebra 2 topic instruction, and students were responsible for watching video lessons at home. When students returned to class, I gave short amounts of practice through individual instruction with feedback, cooperative learning, or small group assistance. Face-to-face instruction was used for three complete lessons. The remainder of this section delves into three key explanations about the innovation: (a) research basis, (b) phases of implementation, and (c) design of classroom experiences and problems.

Research Basis

The primary reason for this innovation was studying its effects on motivation in the mathematics classroom. My research on motivation theories provided the knowledge that motivation consists of extrinsic and intrinsic forces that drive students to begin and sustain tasks in learning (Dimitroff et al., 2018; Kiefer et al., 2015; Nenthien & Loima, 2016). Attard (2012) also pointed out that students' motivation helped to determine if students fully engaged in tasks. In order to provide a framework for student motivation, Keller (1987) introduced The ARCS Model that proposed four categories of motivational design: attention, relevance, confidence, and satisfaction. Baker and Robinson (2017) encouraged teachers to access as many of these categories as possible, when designing instruction.

Therefore, I researched instructional methods that utilized as many of these categories as possible for my students. After an extensive literature search, a single method did not satisfy all of the requirements. Thus, the design of my innovation included (a) problem-based learning in (b) a flipped classroom instructional environment. Each of the methods were used for their results in research.

Problem-based Learning. Problem-based learning is intended to be more like solving problems in the real-world. Problems are ill-structured and require students to access multiple avenues of knowledge during the solving process (Ghufron & Ermawati, 2018; Le Roux, 2008; Savery, 2006). Problem-based learning aligns with categories of The ARCS Model. The real-world scenarios drive student attention within the classroom and encourage them to participate (Akers, 2017; Meredith, 2015). Corso et al. (2013) point out that students begin to see the relevance in their lives. Due to the nature of ill-structured problems, students can also build confidence and satisfaction with mathematics. Instead of rigid single solutions, students can be creative (Akers, 2017; Markušić & Sabljić, 2019). This feature of problem-based learning brings students more enjoyment with problem solving.

Flipped Classroom and Technology Integration. One issue that arose, when researching problem-based learning, was the fear of not adequately addressing Algebra 2 standards given the ill-structured nature of the problems. In order to combat against this issue, I chose to include an additional instructional method that allowed me to give instruction on Algebra 2 standards, as well as include application of technology. Harper and Milman (2016) point out that studies showed increased motivation in students who were allowed to use some form of technology during learning. Students enjoyed lessons that simply provided opportunities for them to use technology during direct instruction or cooperative learning (Attard, 2012; Ghosh, 2017).

Technology-enhanced lessons were not the only option that I explored. I also examined flipped instruction as an instructional method. Traditional instruction in mathematics is where teachers provide direct instruction in-person and practice at home (Amstelveen, 2019; Magliaro et al., 2005). The flipped classroom reverses this structure. Teachers provide instruction through some type of media at home, and then teachers solidify content through practice in the classroom (Amstelveen, 2019). Similar to Eppard and Rochdi (2017), my lessons were videos at home, with practice at school.

Finally, my task was to assimilate the instructional methods for my particular context of studying motivation. Amstelveen (2019) stated that teachers could use the flipped classroom in conjunction with other enrichment activities for students. Eppard and Rochdi (2017) noted that teachers could use the time in class after flipping a lesson to provide differentiated learning for all students. Gaughan (2014) and Meredith (2015) indicated that teachers still needed large swaths of time for planning flipped learning and its corresponding in-class portions. Meredith (2015) stated that many teachers abandoned flipped instruction due to the substantial amount of planning and work involved.

Problem-based Learning in a Flipped Classroom

As I considered all the possibilities for instruction in mathematics, I decided to utilize a classroom instructional model that was a composite of previously described elements. See Figure 3.1 below for a summary of elements utilized in this instructional model. Blended learning environments give students experience with multiple approaches to instruction. Lessons can be direct instruction, technology-enhanced lessons, or completely flipped lessons. Blended classrooms also provide ample time for implementation of problem-based learning. The following section provides phases of my innovation implementation, and the final section provides further details of my problem-based learning in a flipped classroom.

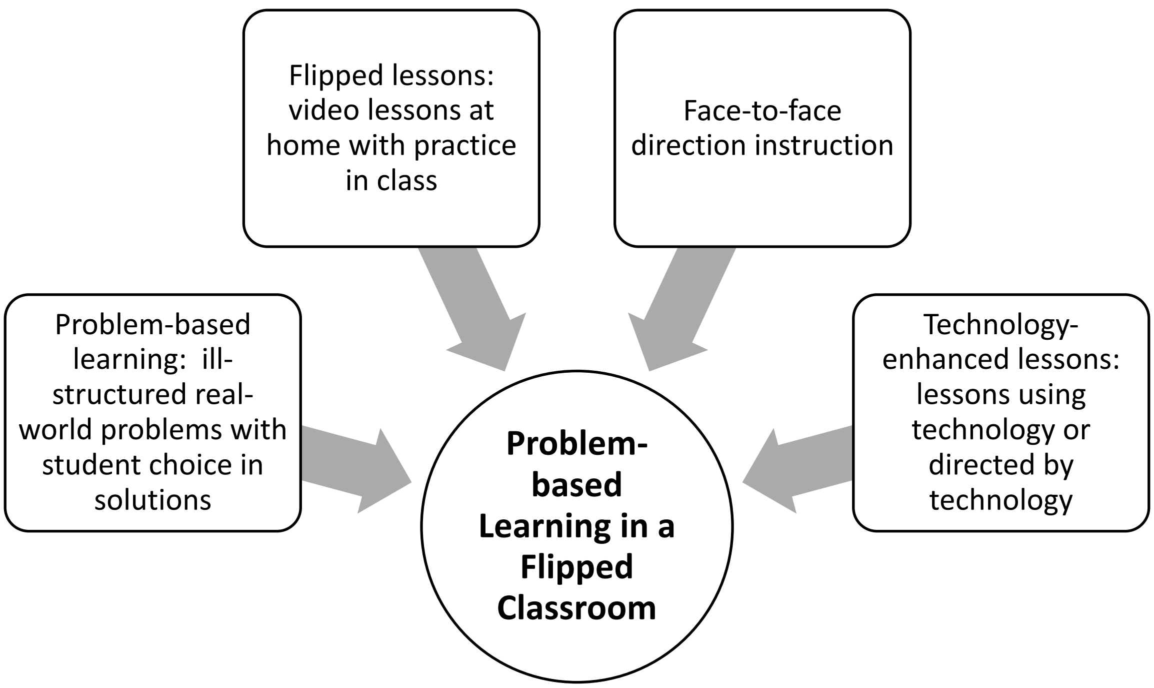


Figure 3.1 *Elements of Innovation Instructional Model*

Phases of Implementation

Phase One and Two. Instruction during the first two phases were face-to-face direct instruction. Although students can benefit from an expert that is modeling problems for them and mathematics being broken into manageable parts, the lack of keeping students' attention and providing relevance leads to low motivation (Amstelveen, 2019; Attard, 2012; Magliaro et al., 2005). Beginning with face-to-face direct instruction also provided contrast with implementation of problem-based learning in a flipped classroom.

The first phase of the study lasted for two weeks. For two weeks, I completed the first Algebra 2 unit on Linear Equation Review. I reviewed lessons on solving, graphing, and writing linear equations. During this unit, I placed three review videos and one assessment on Schoology for students to begin learning technology that will be necessary later. I showed them how to access videos and assessments on Schoology, and I showed them how to answer assessments with math text. These techniques were simply training exercises to improve students' comfort with technology during the innovation phase.

After the first Algebra 2 unit was completed, Phase Two of the study began. For the next two weeks, I continued traditional instruction for a Function Review Algebra 2 unit. I instructed students on features of functions, function transformations, piecewise functions, and solving graphically. During this unit, students were given one flipped lesson in order to prepare them for its utilization during Phase Three.

Phase Three. During this phase, I fully implemented my innovation strategy. Students began problem-based learning and flipped classroom instruction concurrently. The Algebra 2 units of focus were Systems of Equations and Quadratic Functions. During the first Algebra 2 unit, students experienced a variety of instructional methods about graphing systems, solving systems, applications of systems, and linear programming. Flipped lessons required students to watch video lessons at home and practice techniques in class. Direct instruction was utilized for short lessons, such as three-variable linear systems. Cooperative learning provided opportunities for students to explore mathematical content together. During the second Algebra 2 unit, students experienced a variety of instructional methods about writing, solving, graphing, and factoring quadratic functions. More explicit details are given in a later section on the classroom experience and problems during this phase of problem-based learning and flipped classroom instruction.

Design of the Classroom Experience and Problems

The following section presents the design of classes during the first three phases of the innovation. Table 3.2 below gives a summary of the classroom experience during the innovation as well as connections with the instructional model. During Phase One and Two, face-to-face direct instruction was employed. In a typical class, direct instruction involved warm-up problems which reviewed the lesson from the day before or lead to the present day's lesson. Following the warm-up, I introduced students to the new lesson topic. We defined terms and introduced the typical problem structure for that particular lesson. Interspersed throughout the instruction were opportunities for students to complete guided practice with problems. I also preferred to introduce students to at least one real-world application for the topic. After two or three lessons, I gave a quiz that covered the previous topics. After the quiz, I covered two more lessons and gave a final test for the unit.

During Phase Three, students participated in problem-based learning in a flipped classroom instructional environment. Instruction of essential Algebra 2 standards were primarily switched to a flipped classroom style of video lessons at home with guided practice at the beginning of each in-person class (Amstelveen, 2019; Eppard & Rochdi, 2017). Students also used the online application Desmos for exploration activities to examine concepts such as: graphing function transformations by graphing parent functions and transformed functions on Desmos (e.g., $f(x) = x^2$; $g(x) = 2(x - 1)^2 + 5$). Finally, students participated in problem-based learning every day during class, with the exception of the days reserved for final unit tests.

Table 3.2 *Classroom Experience Design and Instructional Model Connections*

Phase	Algebra 2 Lesson	Activity/Lesson Strategy	Component of Instructional Model with Support	Component of ARCS Model with Support
One	Solving Linear Equations, Graphing Linear Equations, and Writing Linear Equations	Face-to-face Direct Instruction	Direct Instruction: Direct instruction will be used during Phase One and Two to deliver content to students and provide a contrast to the main innovation phase (Magliaro et al., 2005).	Confidence: Review of previous content provides opportunities for students to succeed and gain confidence in their math abilities (Hornstra et al., 2018; Mkhize, 2017; Yurt, 2015).
Two	Features of Functions	Face-to-face Direct Instruction	Direct Instruction (Magliaro et al., 2005)	Confidence: Review of previous content (Hornstra et al., 2018; Mkhize, 2017; Yurt, 2015).
Two	Function Transformations	Flipped Lesson	Flipped Lesson: This flipped lesson will be used for introducing students to watching a video at home and practicing during class (Eppard & Rochdi, 2017).	Attention and Satisfaction: Confidence: Review of previous content (Hornstra et al., 2018; Mkhize, 2017; Yurt, 2015).
Two	Piecewise Functions	Group Discovery Activity	Direct Instruction (Magliaro et al., 2005)	Confidence: Review of previous content (Hornstra et al., 2018; Mkhize, 2017; Yurt, 2015).

Phase	Algebra 2 Lesson	Activity/Lesson Strategy	Component of Instructional Model with Support	Component of ARCS Model with Support
Two	Solving Equations and Inequalities by Graphing	Technology Enhanced Lesson	Technology Enhanced Lesson: Students will be allowed to use the online Desmos application (Attard, 2012; Ghosh, 2017; Harper & Milman, 2016; Kalonde, 2017b)	Attention and Satisfaction: Technology enhanced lessons access more student autonomy and engagement, thus increasing satisfaction and attentiveness (Ghosh, 2017; Kalonde, 2017b; Zheng et al., 2016). Confidence: Review of previous content (Hornstra et al., 2018; Mkhize, 2017; Yurt, 2015).
Three	Solving Systems by Graphing and Solving Systems of Equations Algebraically	Flipped Lesson	Flipped Lesson: Students will be given several video lessons to watch at home and practice during class (Eppard & Rochdi, 2017).	Attention, Relevance, Confidence, and Satisfaction: Students interact with real-world problems that encourage them to participate and apply a variety of disciplines (Corso et al., 2013; Ghufron & Ermawati, 2018; Savery, 2006). They gain confidence in their abilities to solve problems (Akers,

Phase	Algebra 2 Lesson	Activity/Lesson Strategy	Component of Instructional Model with Support	Component of ARCS Model with Support
				2017; Ghufron & Ermawati, 2018; Mkhize, 2017).
Three	PBL: Business Plan Problem	Problem-based Learning	PBL: Ill-structured problems applying various content (Ghufron & Ermawati, 2018; Markušić & Sabljić, 2019; Savery, 2006).	Attention, Relevance, Confidence, and Satisfaction: Students interact with real-world problems that encourage them to participate and apply a variety of disciplines (Corso et al., 2013; Ghufron & Ermawati, 2018; Savery, 2006). They gain confidence in their abilities to solve problems (Akers, 2017; Ghufron & Ermawati, 2018; Mkhize, 2017).
Three	Applications of Linear Systems (PBL: Business Plan Problem)	Face-to-face Direct Instruction	Direct Instruction (Magliaro et al., 2005)	Attention and Relevance: real-world problems that encourage participation and application (Corso et al., 2013; Ghufron & Ermawati, 2018; Savery, 2006). Sometimes, application problems (traditional word problem format) can

Phase	Algebra 2 Lesson	Activity/Lesson Strategy	Component of Instructional Model with Support	Component of ARCS Model with Support
				decrease confidence (Le Roux, 2008; Matthews, 2017).
Three	Solving Systems in Three Variables (PBL: Business Plan Problem)	Flipped Lesson	Flipped Lesson: at-home video with classroom practice (Eppard & Rochdi, 2017).	Attention, Relevance, Confidence, and Satisfaction: real-world problems and math success (Akers, 2017; Corso et al., 2013; Ghufron & Ermawati, 2018; Mkhize, 2017; Savery, 2006).
Three	Linear Programming (PBL: Business Plan Problem)	Technology Enhanced Lesson using Desmos Online Application	Technology Enhanced Lesson (Attard, 2012; Ghosh, 2017; Harper & Milman, 2016; Kalonde, 2017b)	Attention, Relevance, Confidence, and Satisfaction: real-world problems and math success (Akers, 2017; Corso et al., 2013; Ghufron & Ermawati, 2018; Mkhize, 2017; Savery, 2006).
Three	Graphing Quadratic Equations	Flipped Lesson and Technology Enhanced Lesson	Flipped Lesson: at-home video with classroom practice (Eppard & Rochdi, 2017)	Attention, Relevance, Confidence, and Satisfaction: real-world problems and math success

Phase	Algebra 2 Lesson	Activity/Lesson Strategy	Component of Instructional Model with Support	Component of ARCS Model with Support
			Technology Enhanced Lesson (Attard, 2012; Ghosh, 2017; Harper & Milman, 2016; Kalonde, 2017b)	(Akers, 2017; Corso et al., 2013; Ghufron & Ermawati, 2018; Mkhize, 2017; Savery, 2006). More student autonomy and engagement, thus increasing satisfaction and attentiveness (Ghosh, 2017; Kalonde, 2017b; Zheng et al., 2016).
Three	PBL: Student App Problem	Problem-based Learning	PBL (Ghufron & Ermawati, 2018; Markušić & Sabljić, 2019; Savery, 2006)	Attention, Relevance, Confidence, and Satisfaction: real-world problems and math success (Akers, 2017; Corso et al., 2013; Ghufron & Ermawati, 2018; Mkhize, 2017; Savery, 2006). More student autonomy and engagement, thus increasing satisfaction and attentiveness (Ghosh, 2017; Kalonde, 2017b; Zheng et al., 2016).

Phase	Algebra 2 Lesson	Activity/Lesson Strategy	Component of Instructional Model with Support	Component of ARCS Model with Support
Three	Writing Quadratic Equations (PBL: Student App Problem)	Flipped Lesson	Flipped Lesson: at-home video with classroom practice (Eppard & Rochdi, 2017)	Attention, Relevance, Confidence, and Satisfaction: real-world problems and math success (Akers, 2017; Corso et al., 2013; Ghufron & Ermawati, 2018; Mkhize, 2017; Savery, 2006). More student autonomy and engagement, thus increasing satisfaction and attentiveness (Ghosh, 2017; Kalonde, 2017b; Zheng et al., 2016).
Three	Solving Quadratic Equations	Flipped Lesson, Technology Enhanced Lesson, and Face-to-face Direct Instruction	Flipped Lesson: at-home video with classroom practice (Eppard & Rochdi, 2017) Technology Enhanced Lesson (Attard, 2012; Ghosh, 2017; Harper & Milman, 2016; Kalonde, 2017b) Direct Instruction (Magliaro et al., 2005)	Attention, Relevance, Confidence, and Satisfaction: real-world problems and math success (Akers, 2017; Corso et al., 2013; Ghufron & Ermawati, 2018; Mkhize, 2017; Savery, 2006). More student autonomy and engagement, thus increasing satisfaction and attentiveness (Ghosh, 2017;

Phase	Algebra 2 Lesson	Activity/Lesson Strategy	Component of Instructional Model with Support	Component of ARCS Model with Support
				Kalonde, 2017b; Zheng et al., 2016).
Three	PBL: Global Warming and Industrialization Problem	Problem-based Learning	PBL (Ghufron & Ermawati, 2018; Markušić & Sabljić, 2019; Savery, 2006)	Attention, Relevance, Confidence, and Satisfaction: real-world problems and math success (Akers, 2017; Corso et al., 2013; Ghufron & Ermawati, 2018; Mkhize, 2017; Savery, 2006).
Three	Factoring and Solving Quadratic Equations (PBL: Global Warming and Industrialization Problem)	Flipped Lesson, Technology Enhanced Lesson, and Face-to-face Direct Instruction	Flipped Lesson: at-home video with classroom practice (Eppard & Rochdi, 2017) Technology Enhanced Lesson (Attard, 2012; Ghosh, 2017; Harper & Milman, 2016; Kalonde, 2017b) Direct Instruction (Magliaro et al., 2005)	Attention, Relevance, Confidence, and Satisfaction: real-world problems and math success (Akers, 2017; Corso et al., 2013; Ghufron & Ermawati, 2018; Mkhize, 2017; Savery, 2006).
Three	PBL: Consumer Sales Problem	Problem-based Learning	PBL (Ghufron & Ermawati, 2018; Markušić & Sabljić, 2019; Savery, 2006)	Attention, Relevance, Confidence, and Satisfaction: real-world

Phase	Algebra 2 Lesson	Activity/Lesson Strategy	Component of Instructional Model with Support	Component of ARCS Model with Support
	PBL: Investment Problem	Problem-based Learning		problems and math success (Akers, 2017; Corso et al., 2013; Ghufron & Ermawati, 2018; Mkhize, 2017; Savery, 2006). More student autonomy and engagement, thus increasing satisfaction and attentiveness (Ghosh, 2017; Kalonde, 2017b; Zheng et al., 2016).

Flipped instruction lessons were posted on Schoology at least two days before each lesson would be practiced or applied during class. Students were required to watch lesson videos for homework. Each week, I wanted a preset schedule for learning, but adjustments were made as needed for learners. During the spring semester, there were several interruptions that removed a majority of students from class, such as field trips, class meetings, and special visitors. Due to these interruptions, I was unable to keep each week on exactly the same schedule. However, Table 3.3 provides an ideal schedule for learning and instruction each week. On Monday, Wednesday, and Thursday, students begin class with 25 minutes of guided practice or a cooperative learning activity connected directly to the previous night's lesson. The remaining hour of class is utilized for problem-based learning. Both Amstelveen (2019) and Eppard and Rochdi (2017) encourage teachers to utilize the extra time of the flipped classroom to provide enrichment or differentiated learning. Although, the days of the week were not consistent, I still attempted to follow a similar pattern to the ideal schedule. The major adjustment that I made was giving students two small six- and 13-question assessments and two larger 25-question assessments. The small assessments were given at the middle of the units after three lessons. The large assessments were given at the end of each unit. Guided practice at the beginning of each class allowed me to differentiate for students. Problem-based learning was enrichment that accessed attention, relevance, confidence, and satisfaction from the ARCS model of motivation (Akers, 2017; Corso et al., 2013; Markušić & Sabljić, 2019; Meredith, 2015). Students worked on problem-based learning in the remaining time after guided practice or assessments.

Table 3.3 *Ideal Weekly Schedule for Learning and Instruction*

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	Guided practice or cooperative learning (25min) PBL work for 60 minutes	Assessment (2-5 questions) Direct instruction PBL work for 60 minutes	Guided practice or cooperative learning (25min) PBL work for 60 minutes	Guided practice or direct instruction (25min) PBL work for 60 minutes	Assessment on weekly learning (15-20 questions) PBL work for remainder	
Students watch video for first or second time	Flipped lesson posted for Wednesday	Students watch video Flipped lesson posted for Thursday	Students watch video for first or second time			Flipped lesson posted for Monday

Problem-based Learning Examples

Problem-based learning included five problems that students worked on concurrently with Algebra 2 coursework. Each problem-based learning example is outlined in Table 3.4 below. Each problem was introduced with a central question, and students provided their solutions in a variety of methods. Students also helped me create their own grading rubric for each problem. On the first problem, I asked students to create a business plan that could earn them loans from a bank. For the second problem, students were asked if there was a way to encourage students to participate in school with phone apps. Then, they were asked to define what their app will do and include as features. For the third problem, students needed to provide solutions for addressing global warming and bringing industrialization to underdeveloped countries. The fourth problem required students to provide solutions for how they would decide what to include in a potato chip variety bag (Kaplinsky, 2015). The final problem asked students to provide their solutions to transform $10,000 into $100,000. Students presented their solutions to the problems utilizing a variety of methods.

Table 3.4 *Problem-based Learning Examples*

Problem	Central Question	Time
Business Plan	What type of business would you start in your home town, and why? Create a business plan that would earn a bank loan for your business.	9 days
Student App	What designs and features would you include on a cell phone app to encourage student participation in school?	4 days

Problem	Central Question	Time
Global Warming and Industrialization	How do you reduce global warming and increase industrialization in underdeveloped countries?	9 days
Consumer Sales	In a potato chip variety pack, how many of each type of chip would you include?	1 day
Investment	How would you transform $10,000 into $100,000? Give your classmates a step-by-step process.	3 days

Data Collection Methods

Quantitative and qualitative data was collected to explore students' motivation in mathematics classrooms before, during, and after problem-based learning in a flipped classroom instructional environment. Students' responses on a survey about motivation and motivational subscales gave quantitative values for analysis. Teacher observations, student journals, and student interviews were qualitative data sources utilized for this study on student motivation. Creswell and Creswell (2018) emphasized the importance for researchers to triangulate from different data sources to ensure validity of their study. The mixed methods design also allows a more in-depth analysis (Creswell & Creswell, 2018; Mertler, 2019). Quantitative data was a primary driver of my research design, but qualitative data was utilized to gain more insight. Alignment of data sources with research questions from the study is provided in Table 3.5 below.

Table 3.5 *Research Question and Data Collection Alignment*

Research Question	Data Collection Method
1) What was the impact of problem-based learning in a flipped classroom instructional environment on students' motivation in mathematics?	Motivation in Mathematics Survey developed from the Academic Achievement and

Research Question	Data Collection Method
	Motivation Survey by Jiang et al. (2018)
2) What was the impact of problem-based learning in a flipped classroom instructional environment on students' self-efficacy in mathematics?	Motivation in Mathematics Survey developed from the Academic Achievement and Motivation Survey by Jiang et al. (2018)
3) What was the impact of problem-based learning in a flipped classroom instructional environment on students' mathematics achievement on Systems of Equations and Quadratic Functions?	Diagnostic Test on Systems of Equations and Quadratic Functions
4) What were students' perceptions of problem-based learning in a flipped classroom instructional environment?	Teacher Observation Journal Student Journals Focus Group Interview

Motivation in Mathematics Survey

This study's first portion of quantitative data collection utilized a One-Group Pretest-Posttest Design (Creswell & Creswell, 2018). Students' scores on the Motivation in Mathematics Survey provided data for comparison. I crafted and renamed this survey by utilizing motivation items from the Academic Achievement and Motivation Survey by Jiang et al. (2018). The Academic Achievement and Motivation Survey was developed specifically to measure adolescent students in mathematics courses. Although the Academic Achievement and Motivation Survey (Jiang et al., 2018) included items not specific to motivation, Pintrich, Smith, Garcia, and McKeachie (1991) gave precedence for allowing surveys to be limited to motivation scales alone. Therefore, I limited subscales as described in the following section, and renamed my shortened version to Motivation in Mathematics Survey.

Jiang et al. (2018) measured motivation in their survey utilizing the constructs of expectancy, value, and cost. They also included a section on classroom affect that measured student feelings about classroom environment. My definition of motivation included intrinsic and extrinsic forces that drove students to begin and sustain tasks. Therefore, I chose these four sections for my Motivation in Mathematics Survey. These four sections comprised 27 items: six items on *Self-efficacy*, six items on *Task Value*, 12 items on *Cost*, and three items on *Positive Classroom Affect*. The *Self-efficac*y section included items such as, "I'm certain that I can understand what is taught in math class" and "I expect to do very well in math class." The *Task Value* section included items such as, "I think I will be able to use what I learn in math class in other places" and "I think math is useful for me to learn." The *Cost* section included items such as, "Doing well in math requires more effort than I want to put into it" and "It requires too much effort for me to get a good grade in math." The *Positive Classroom Affect* section included items such as, "Most of the time, being in math class puts me in a good mood" and "I like being in math class."

Students responded to items about different motivational orientations on a seven point Likert scale ranging from 1: *Not true at all of me* to 7: *Very true of me* (Jiang et al., 2018). The complete list of items is located in Appendix A, and is organized by motivational subscales. The items were given to students through Google Forms. Overall motivation pretest scores and posttest scores were collected and exported to a comma-separated values (CSV) document in Excel. Another document also separated the self-efficacy scores for analysis. Both documents were password protected.

When Jiang et al. (2018) created the survey items, they were targeted to test adolescents due to the declining motivation during secondary school years. Jiang et al. (2018) stated that the survey items referred to "math class or math as a subject domain" (p. 141). Survey items were all developed from previously used measures in order to ensure content validity (Jiang et al., 2018). Cronbach's alpha was used to measure the internal reliability coefficient for each category. Each subscale of motivation measure displayed the following Cronbach alphas: self-efficacy had a coefficient of $\alpha = .94$, task value had a coefficient of $\alpha = .87$, cost had a coefficient of $\alpha = .89$, and positive classroom affect had a coefficient of $\alpha = .93$ (Jiang et al., 2018).

Teacher Observations

In addition to quantitative data collection, I employed observational techniques to explore students' motivation before and during problem-based learning in a flipped classroom instructional environment. Throughout the research process, I kept an observation journal about all aspects of the innovation, and included reflexive notes intertwined with the observations. The journal began with general observations about students' demographic backgrounds and recent experiences with digital learning. The remainder of the teacher observation journal spanned the innovation period from February 10 through April 5. Each day, including several weekends, I made observation notes about students participating in the innovation and reflexive notes about my experiences and perceptions during the innovation. Creswell and Creswell (2018) indicated that observational notes can be a simple document with a line down the center dividing descriptive notes from reflexive notes. Mertler (2019) also used a similar design with observations and observer's comments. Researchers can record interesting events or students with their reactions and thoughts (Creswell & Creswell, 2018).

I observed behaviors during the traditional mathematics instruction and during the innovation phase. I recorded when students displayed off-task behaviors and were distracted by inappropriate cell phone use. Off-task behaviors included talking to classmates about unrelated topics, personal grooming, and working on assignments for other courses. Inappropriate cell phone use included social media for personal topics, taking selfies, and utilizing cheating assistance apps like photomath. I also recorded when students were answering questions, asking questions, and offering mathematical insights. For these behaviors, I was primarily concerned with significant occurrences. I did not want to interrupt the flow of thought during class. However, I summarized questions asked or answered at a later point in class. Several times during the innovation period, I recorded direct quotes immediately in my observation journal. I noted when students gave insights into mathematics such as real-world connections or connections to previous material. As researchers suggested, emergent behaviors were adapted or added as the study evolved (Creswell & Creswell, 2018; Mertler, 2019; Tracy, 2020).

Student Journals

Furthermore, students were asked to respond to five journal prompts throughout the innovation period. Journal prompts were provided, but students were encouraged to write freely about their experiences in math class. Journal prompts were developed from research by Rimm-Kaufman (2010) and Patrick et al. (2007). Journal prompts were connected to classroom experiences as well. Most of the prompts begins with "For your journal today, tell me about your experiences in math class this week." They extend with, “You can think about the following prompts, but feel free to tell me whatever you truly think: This week in math class, I worked as hard as I could because…. and Math class was fun/boring this week because…”. Appendix B includes complete journal prompts by date. Students responded to journal prompts on Google Forms. Responses were password protected through district email.

Student Interviews

The students and I engaged in semi-structured interviews and a focus group interview during the study. Interviews are common data collection devices used in qualitative studies (Creswell & Creswell, 2018; Tracy, 2020). Interviews with students gave them the ability to provide their voice in the discussion. The interviews gave me the ability to further examine students’ experiences during problem-based learning in a flipped classroom instructional environment and its impact on motivation.

Semi-structured interviews. I conducted short semi-structured interviews in the middle of class periods that involved problem-based learning with one-on-one interactions and cooperative learning. Responses to these short informal interviews, about one to two minutes in length, were recorded in my observational notes. They had a frequency of no more than once per week for each student interviewed. Typically, these interviews were only one or two questions. Questions for these interviews focused on why the students were performing certain actions, what their feelings were about problem-based learning, and how they viewed the utility of mathematics.

Focus group interview. I conducted one focus group interview with a sample of the Algebra 2 participants. In order to obtain more diversity in characteristics, I utilized a maximum variation sample (Tracy, 2020). Because of the emergent nature of qualitative research, I found themes that were unexpected, but adhered to the same sample of students for the focus group interview (Creswell & Creswell, 2018). I looked at all of my Algebra 2 students' backgrounds at the beginning of the semester in order to ensure that my sample included students with different cultural/ethnic backgrounds, socioeconomic backgrounds, gender, and previous mathematics performances. The goal was to obtain a diverse sample to increase the range of the collected data for different characteristics and decrease bias. I selected six students for the focus group interview sample. There were three Sophomores and three Juniors. Also, four female and two male students were selected. This ratio was used to match the ratio of demographics within the classroom as a whole.

The focus group interview occurred after the end of the innovation phase. The interview was 50 minutes long. Questions for this interview were adapted from the research of Patrick et al. (2007) and Rimm-Kaufman (2010). Also, questions were selected from responses to semi-structured interviews and journal prompts. Peer experts and external experts were asked to review the interview questions for content validity. Appendix C contains a list of questions that were used during the focus group interview. Some questions were adjusted or omitted during the live interview. I recorded an MP3 file of the interview using Apple GarageBand on an Apple Macintosh computer. Recording allowed me to pay close attention to the respondents and make detailed reflexive notes during the interview process as well.

Diagnostic Test on Systems of Equations and Quadratic Functions

The Diagnostic Test on Systems of Equations and Quadratic Functions was comprised of 35 items that examined students' mathematics achievement in the two

Algebra 2 units during my innovation period. The items were correlated to the state College and Career Ready Algebra 2 Standards for 2015. They were the Algebra 2 standards utilized by the Pali County School District. The following standards were utilized:

- Creating Equations (A2.ACE.1,2,3),
- Reasoning with Equations and Inequalities (A2.AREI.4b,7,11),
- Structure and Expressions (A2.ASE.2,3b),
- Building Functions (A2.FBF.1b,3),
- Interpreting Functions (A2.FIF.4,5,7), and
- Complex Number System (A2.NCNS.1).

The details of each separate standard and associated sample items from the diagnostic test are given in Table 3.6 below. Multiple choice answers are not included in Table 3.6 below. Four items were also selected due to my experience with students' needs for future courses, such as Precalculus and Calculus. These items also contained review of previous concepts from Algebra 1 and prepared students for A2.AREI.4b,7,11 and A2.FBF.3.

Table 3.6 *Algebra 2 Standards and Associated Sample Questions*

Algebra 2 Standard	**Standard Details**	**Sample Question from Diagnostic Test**
A2.ACE.1	Create and solve equations and inequalities in one variable that model real-world problems involving linear, quadratic, simple rational, and exponential relationships. Interpret the solutions and determine whether they are reasonable.	A toy cannon ball is launched from a cannon on top of a platform. The equation $h(t) = -5t^2 + 20t + 4$ gives the height h, in meters, of the ball t seconds after it is launched. Does the ball reach a height of 12 m?

Algebra 2 Standard	Standard Details	Sample Question from Diagnostic Test
A2.ACE.2	Create equations in two or more variables to represent relationships between quantities. Graph the equations on coordinate axes using appropriate labels, units, and scales.	What is the equation written in vertex form of a parabola with a vertex of (–1, 8) that passes through (1, 0)?
A2.ACE.3	Use systems of equations and inequalities to represent constraints arising in real-world situations. Solve such systems using graphical and analytical methods, including linear programing. Interpret the solution within the context of the situation. (Limit to linear programming.)	Shandra is on vacation and wants to buy souvenirs for at least eight friends. A postcard book costs \$2.50 and a magnet costs \$4.00. She can spend up to \$30 altogether. Which system of inequalities represents the situation? Which graph represents the system?
A2.AREI.4b	Solve mathematical and real-world problems involving quadratic equations in one variable: b. Solve quadratic equations by inspection, taking square roots, completing the square, the quadratic formula and factoring, as appropriate to the initial form of the equation. Recognize when the quadratic formula gives complex solutions and write them as $a + bi$ for real numbers a and b.	Solve the equation $x^2 + x = 12$.
A2.AREI.7	Solve a simple system consisting of a linear equation and a quadratic equation in two variables algebraically and graphically. Understand that such systems may have zero, one, two, or infinitely many solutions. (Limit to linear equations and quadratic functions.)	Use substitution to solve the system $\begin{cases} y = -\frac{1}{2}x^2 \\ y = x - 4 \end{cases}$
A2.AREI.11	Solve an equation of the form $f(x) = g(x)$ graphically by	Solve $\lvert x + 3\rvert - 1 = (x + 2)^2$

Algebra 2 Standard	Standard Details	Sample Question from Diagnostic Test
	identifying the x- coordinate(s) of the point(s) of intersection of the graphs of $y = f(x)$ and $y = g(x)$.	by graphing.
A2.ASE.2	Analyze the structure of binomials, trinomials, and other polynomials in order to rewrite equivalent expressions.	Solve $0 = x^2 - 10x + 30$ by completing the square.
A2.ASE.3b	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression: b. Determine the maximum or minimum value of a quadratic function by completing the square.	A function is defined by the equation $y = x^2 + 3x + 1$. Which statements are true? Select all that apply.
A2.FBF.1b	Write a function that describes a relationship between two quantities: b. Combine functions using the operations addition, subtraction, multiplication, and division to build new functions that describe the relationship between two quantities in mathematical and real-world situations.	Students can utilize this standard for the following: Solve the system of equations. $\begin{cases} x + y + z = 9 \\ -2x + y + 2z = 3 \\ x - 4y - z = 2 \end{cases}$
A2.FBF.3	Describe the effect of the transformations $kf(x)$, $f(x) + k$, $f(x + k)$, and combinations of such transformations on the graph of $y = f(x)$ for any real number k. Find the value of k given the graphs and write the equation of a transformed parent function given its graph.	Identify the translations of the parent function $f(x) = x^2$ that give $g(x) = (x - 5)^2 - 4$.
A2.FIF.4	Interpret key features of a function that models the relationship between two quantities when given in graphical or tabular form. Sketch	Over what interval is the graph of $y = 2 + (x - 3)^2$ increasing?

Algebra 2 Standard	Standard Details	Sample Question from Diagnostic Test
	the graph of a function from a verbal description showing key features. Key features include intercepts; intervals where the function is increasing, decreasing, constant, positive, or negative; relative maximums and minimums; symmetries; end behavior and periodicity.	
A2.FIF.5	Relate the domain and range of a function to its graph and, where applicable, to the quantitative relationship it describes.	What are the domain and range of the function $h(x) = -12\,(x - 4)^2 + 3$?
A2.FIF.7	Graph functions from their symbolic representations. Indicate key features including intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior and periodicity. Graph simple cases by hand and use technology for complicated cases.	The path of a projectile launched from a 16-ft-tall tower is modeled by the equation $y = -16t^2 + 64t + 16$. Which is the correct graph of the equation? The path of a projectile launched from a 16-ft-tall tower is modeled by the equation $y = -16t^2 + 64t + 16$. What is the maximum height, in feet, reached by the projectile?
A2.NCNS.1	Know there is a complex number i such that $i^2 = -1$, and every complex number has the form $a + bi$ with a and b real.	Write the product $(4 + i)(4 - i)$ in the form $a + bi$.

Pali High School used an online Algebra 2 textbook from Pearson. The online Pearson textbook was employed to create the Diagnostic Test on Systems of Equations and Quadratic Functions. Pearson aligned items that were utilized to the state College and Career Ready Algebra 2 Standards from 2015. Even though this function was well established for validity, I wanted further confirmation that my diagnostic test measured students' achievement on Systems of Equations and Quadratic Functions. To further establish test validity, I employed the assistance of the math department head at my high school and the director of secondary math education for Pali County School District. Each person received a copy of the test with standards that each item was intended to measure. They confirmed that my diagnostic test measures what it was intended to measure. Feedback from the director of secondary math education for improvement of the diagnostic test was reviewed and implemented.

Students took the Diagnostic Test on Systems of Equations and Quadratic Functions through their online textbook. The online textbook was password protected on student and teacher accounts. They had one class period to complete the test before innovation period, and one class period after the innovation period for the second measure of their achievement. A copy of all items for the Diagnostic Test on Systems of Equations and Quadratic Functions is found in Appendix D. Scores from preinnovation and postinnovation measures were transferred as a CSV file to an Excel document that was password protected.

Data Analysis

Both quantitative data and qualitative data were analyzed in this mixed methods study. Research questions, data collection sources, and analysis alignment are outlined in Table 3.7 below. The following section discusses data analysis techniques that were utilized for each data source and corresponding research questions.

Table 3.7 *Data Analysis Alignment*

Research Question	Data Collection	Analysis
1) What was the impact of problem-based learning in a flipped classroom instructional environment on students' motivation in mathematics?	Motivation in Mathematics Survey	Descriptive statistics and Paired samples *t*-test
2) What was the impact of problem-based learning in a flipped classroom instructional environment on students' self-efficacy in mathematics?	Self-efficacy subscale from the Motivation in Mathematics Survey	Descriptive statistics and Paired samples *t*-test
3) What was the impact of problem-based learning in a flipped classroom instructional environment on students' mathematics achievement on Systems of Equations and Quadratic Functions?	Diagnostic Test on Systems of Equations and Quadratic Functions	Descriptive statistics and Paired samples *t*-test
4) What were students' perceptions of problem-based learning in a flipped classroom instructional environment?	Teacher Observation Journal Student Interviews and Journals	Inductive analysis

Quantitative and Qualitative Analysis

Pretest and posttest scores from the Motivation in Mathematics Survey and the Diagnostic Test on Systems of Equations and Quadratic Functions were analyzed utilizing the same statistical techniques at the conclusion of the study, to limit any type of bias towards students with lower scores. JASP statistical analysis software was utilized to obtain descriptive statistics and inferential statistics. The level of significance in the differences between pretest and posttest scores for both measures were examined with a Paired samples *t*-test at an $\alpha = 0.05$ significance level (Adams & Lawrence, 2019; Fink, 2017). Qualitative data, such as teacher observations, student journals, and student interviews, were analyzed to give deeper insight on how problem-based learning in a flipped classroom instructional environment impacted student motivation. The process that I used for my qualitative analysis was a general inductive approach, as encouraged by Liu (2016) and Thomas (2006). I scrutinized my data through multiple cycles that are outlined later in order to truly ruminate on the findings that were being suggested by the data. A cyclical approach allowed me to examine emerging categories and themes, relate to previous theories, and refine my own analysis (J. Creswell, 2017; Saldaña, 2021; Tracy, 2020). I utilized the following four stages for my cyclical approach: (a) managing data and initial reading, (b) initial coding and emergent coding, (c) developing themes and evaluating interpretations, and (d) presenting findings. These stages were based on the stage approach outlined by Creswell (2017).

Procedures and Timeline

The research procedures were divided into five major phases. These phases are listed below and outlined in Table 3.8 that follows:

Phase 1: Participant Identification

Phase 2: Pretest Data Collection

Phase 3: Problem-Based Learning and Data Collection

Phase 4: Posttest and Interview Data Collection

Phase 5: Data Analysis

Table 3.8 *Procedures and Timeline for Research Phases*

Phase	Procedures	Approximate Timeline
Phase 1: Participant Identification	1. Student demographic and interest surveys were given on the first day of class. 2. Traditional instruction used for Linear Equation Review.	3 weeks January 4 – 24

Phase	Procedures	Approximate Timeline
	3. I taught students how to access instructional videos and assessments. 4. Students completed some eLearning due to a snow storm closing school. 5. During the third week, I sent home consent forms for students and parents/guardians. 6. During this phase, and all subsequent phases, I maintained a researcher's journal that included my observation field notes during each week.	
Phase 2: Pretest Data Collection	1. Students were given the Diagnostic Test on Systems of Equations and Quadratic Functions. 2. Traditional instruction continued for a Function Review unit. I included one flipped lesson for troubleshooting technology and training students. 3. I gave students the Motivation in Mathematics Survey.	2.5 weeks January 25 – February 11

Phase	Procedures	Approximate Timeline
Phase 3: Problem-Based Learning and Data Collection	1. Flipped and hybrid technology mediated instruction began on Systems of Equations. Concurrently, problem-based learning also started. 2. 1st problem: Business Plan Problem (9 days) 2nd problem: Student App Problem (4 days) 3rd problem: Global Warming and Industrialization Problem (9 days) 5th problem: Consumer Sales Problem (1 day) 6th problem: Investment Problem (3 days) 3. On five separate classes, students completed a journal entry. 4. I observed and questioned individual students and groups during problem-based learning lessons. Observations were recorded in my researcher's journal.	6.5 weeks February 14 – April 8
Phase 4: Posttest and Interview Data Collection	1. Students were given the Motivation in Mathematics Survey again. 2. Students were also given the Diagnostic Test on Systems of Equations and Quadratic Functions. 3. During the second week, I also conducted a focus group interview. 4. At the end of the second week, I began transcribing the focus group interview.	2 weeks April 4 – 14

Phase	Procedures	Approximate Timeline
Phase 5: Data Analysis	1. I performed statistical analysis on the diagnostic pretest and posttest, as well as the motivation survey. 2. I wrote basic results, and made note of possible conclusions in my researcher's journal. 3. During April and May, I transcribed the focus group interview and other quotes from semi-structured interviews during class. I provided the transcripts to the participating students for member checking. 4. I began inductive analysis on my observation notes and student interviews during August through December. 5. After this phase, I allowed students to read my current analysis and give me feedback.	8.5 months April 11 – December 31

Phase 1: Participant Identification

During the first phase, the primary goal was to learn about my students and obtain initial data to guide lesson preparation and meeting their needs. I also obtained consent for students to participate in my research. Phase one lasted for two weeks. Throughout this initial data gathering period, I taught lessons utilizing traditional mathematics instructional techniques. Logistics of the Schoology online learner management system were also emphasized. I taught students how to access materials from our online course page. I organized digital folders on our materials page by unit of study. Students practiced opening video files and PDF files for lessons and assignments. They also practiced inputting math text through two online assignments. Throughout the first phase I also made sure students were familiar with using Desmos online calculator.

Phase 2: Pretest Data Collection

The primary goal of phase two was to obtain pretest data for motivation and mathematics. Phase two lasted two and a half weeks. Students took the Diagnostic Test on Systems of Equations and Quadratic Functions that addressed Algebra 2 standards during the intervention (see Appendix D). Students also responded to the Motivation in Mathematics Survey (see Appendix A) based upon the Academic Achievement and Motivation Survey by Jiang et al. (2018). During this phase, I continued to utilize traditional mathematics instruction. However, I did administer one flipped lesson, which gave me the opportunity to help students troubleshoot technology problems and transition to the next phase.

Phase 3: Problem-Based Learning and Data Collection

This phase was the main portion of my action research innovation, and lasted six and a half weeks. Students transitioned to problem-based learning while I utilized a flipped classroom instructional environment. Students had flipped video lessons and short in-class practice and application of content. The remainder of each class period was spent on problem-based learning experiences. There were five problem-based learning experiences during this phase. The Business Plan Problem and Global Warming and Industrialization Problem lasted for nine days each. Students worked during class, but also worked over a couple weekends as well. The Student App Problem lasted for four days in class. The Consumer Sales Problem was a single day in class, and the Investment Problem lasted for three days in class. Data collection during this phase was student mathematics journals (see Appendix B) and observations recorded in my researcher's journal from in class observations and short interviews with students. Students completed journal entries on five separate classes separated by no more than two weeks. During class each day, I observed student behaviors and communications. I recorded these along with my own reflexive thoughts. I also chose random students to interview with quick questions during their problem-based learning work time. The interviews were no longer than one to two minutes and were recorded in my observation notes. Questions focused on why they were performing certain actions and their experiences during problem-based learning.

Phase 4: Posttest and Interview Data Collection

The chief goal of the fourth phase was to collect final data points. It lasted two weeks. Students took the Diagnostic Test on Systems of Equations and Quadratic Functions for a posttest. They also responded to the Motivation in Mathematics Survey for a second time. It was completed on Monday and Tuesday of this week. On the following Thursday, I conducted a focus group interview (see Appendix C) with a group of six students. I tried to match student demographics as closely as possible to the total class ratio. There were three sophomores and three juniors. There were four females and two males. Finally, I also selected my only Hispanic student to maintain more diversity in the interview group. The interview lasted for fifty minutes and was recorded on my computer. I also transcribed the interview over the next two weeks.

Phase 5: Data Analysis

The final phase was originally supposed to be a shorter time period, but lasted for eight months. I provided the interview transcriptions to the participating students for review during the month of May. Students did not suggest changes to the transcription and indicated that it was faithful to what was said. Initial statistical analysis and results on the motivation survey and diagnostic test were performed during July. Results were recorded and are outlined in Chapter 4. The largest portion of this phase was from August to December. I performed a general inductive analysis on my qualitative data. During this time, I participated in peer debriefing with my dissertation chair. After finalizing my findings, I sent a rough draft to my students in order to solicit feedback. I allowed them to read my analysis and give me feedback on my conclusions to that point. Students did not provide any feedback for, or against, my findings.

Rigor & Trustworthiness

Rigor and trustworthiness are strategies that a researcher utilizes to certify the quality of their research and data (Mertler, 2019). Creswell and Creswell (2018) also state that although validity for qualitative data is not the same as quantitative data, it is still essential for researchers to have steps in place to guarantee that their data and findings are accurate and trustworthy. To ensure that my research was of the highest quality, I implemented several methods that confirmed my research to be accurate and trustworthy. The validity and reliability of my quantitative measures of motivation and achievement were already established in the data collection section. I incorporated several methods for rigor and trustworthiness in qualitative analysis. Those methods outlined in this section were as follows: a) triangulation, b) member checking, c) peer debriefing, and d) an audit trail.

Triangulation

Tracy (2020) points out that triangulation is a process of utilizing multiple types of data to gain multiple viewpoints of the research. First, my research incorporated a mixed methods design with quantitative and qualitative data sources. Multiple types of data sources provided triangulation by negating limitations of each source and maximizing benefits of each source (Shenton, 2004). Maxwell (2010) points out that triangulation moves beyond simply having two types of data to discussing how we interpret the meaning of the interaction between the two types of data. More complete pictures emerge through triangulation. Additional evidence of triangulation was achieved with multiple qualitative data sources as well. Tracy (2020) states that triangulation is the act of making sure that data sources converge on a singular reality, and it strengthens research findings. Teacher observations, student journals, and student interviews were triangulated to create thick, rich descriptions of motivation themes in my Algebra 2 class. Thick, rich descriptions are used to accurately portray the situations and environments of the research in order to improve the trustworthiness of the research (Shenton, 2004). All of these data sources were used to build themes that cut across all data sources.

Member Checking

Furthermore, member checking was applied in multiple formats. Member checking is viewed by some as the main support to qualitative data credibility (Guba & Lincoln, 1989, as cited in Shenton, (2004). Mertler (2019) states that member checking can occur when transcripts and observations are shared with participants to review accuracy. Two and a half weeks after the focus group interview was completed, I had each respondent examine the transcription of the interview and accompanying field notes (Shenton, 2004). I gave them opportunity to provide feedback at the end of class one day. Students did not suggest changes to the transcription and indicated that it was faithful to what was said before I began the process of analyzing for themes.

Additionally, students were able to read over the findings and interpretations before my final document. Creswell and Creswell (2018) contended that this method should be utilized instead of sharing transcripts. Students had the ability to correct my findings if I was allowing my own perspectives to overshadow their thoughts (Shenton, 2004). For my research, I gave participants multiple opportunities to give me feedback. After allowing them to read findings, I offered opportunities for feedback sessions after school if students desired to come to me in person. These feedback sessions were offered before final submission of my study.

Peer Debriefing

Peer debriefing is a way to receive feedback on a study from someone who is close to the local situation, but not directly involved in the study. Fresh perspectives from a peer can force the researcher to challenge their postulations (Shenton, 2004). Mertler (2019) calls peer debriefing "the act of using other professionals (perhaps a colleague or a critical friend) who can help you reflect on the research by reviewing and critiquing your processes of data collection, analysis, and interpretation" (p. 143). I obtained the assistance of Dr. Bobo for peer debriefing. Dr. Bobo had over 30 years of experience teaching mathematics at Pali High School, and also designed and implemented her own doctoral study. Dr. Bobo checked my intervention strategies for relevance and rigor in mathematics. With her amount of experience in the classroom, she was able to evaluate my emerging themes obtained from qualitative data.

Herr and Anderson (2005) also point out that problems which arise in a local context should have solutions that are deemed appropriate for that context. Dr. Bobo's familiarity with the Pali community and students allowed her to evaluate my findings for trustworthiness. Her wealth of knowledge was critical to examining my study. Above all else, Dr. Bobo was not afraid to be completely honest with anyone asking for an opinion. She has been a resource and sounding board for my teaching career from day one.

Creswell and Creswell (2018) and Mertler (2019) both emphasize that a knowledgeable outsider can provide valuable feedback for a study. Peer debriefing was also completed by my dissertation chair and committee. Even though they were familiar with my study, they were not intimately involved in my local setting. They were able to provide fresh eyes on my study, and they were able to suggest edits. Shenton (2004) states that researchers can become so absorbed in the participant's culture that professional judgements are swayed. My dissertation chair and committee also provided insight into theme development and support that I was missing with constantly being so close to the study. They drew my attention to possible flaws in my interpretations of the evidence (Shenton, 2004).

Audit Trail

Finally, I kept a researcher's journal as an audit trail. The journal can give other researchers the ability to replicate the study in their own unique settings. Shenton (2004) states that detailed reporting of the entire research process addresses the dependability issue within qualitative results. It also gave me the ability to analyze my thought processes throughout the entire study. Shenton (2004) stats that an audit trail details the researchers' thoughts on data and emerging constructs, and is essential to establishing trustworthiness. When finalizing my findings and interpretations, I was also able to review evidence for themes and why I made certain interpretations. The researcher's journal was documentation of my decision making.

Plan for Sharing and Communicating Findings

Sharing and communicating findings for action research is an essential piece of improving problems of practice within local contexts (Herr & Anderson, 2005). Teachers from the community under study may be experiencing the same concerns. Manfra and Bullock (2014) point out that action research is known as being characteristic of a reflective practitioner. This action research study was not my first attempt at improving my practice, but it did begin a more formal cycle of implementing change and examining results. I shared results with the primary stakeholder first: my students. Then, I will expand my presentation of findings to others with informal meetings in the local context and conferences with organizations outside the local context. At each stage, I also hope to receive valuable feedback from others interested in my study.

At the completion of the study, motivation pretest and posttest scores were shared with student participants through a statistical infographic. The infographic compared scores from the pretest and the posttest. One of the goals for action research is to improve teaching and solve a problem of practice (Belzer & Ryan, 2013; Johnson & Christensen, 2017). Even though I was unable to utilize feedback forms, Pintrich et al. (1991) give examples of teacher feedback forms that help students contemplate motivation constructs. Following the study, I held an informal discussion about motivation in mathematics with my Algebra 2 class. I allowed them to express their thoughts about motivation, problem-based learning, the flipped classroom, and general thoughts about my research.

Students are not the only stakeholders that could have an interest in the results from my research. Therefore, I will encourage students, parents, administrators, and colleagues to read the research results and come to an informal meeting about the results. Herr and Anderson (2005) emphasize the importance of sharing action research findings within the local context to address the needs in the community that is being studied. Time constraints have limited the implementation of an informal meeting. However, my plans is to have an informal meeting as an after-school social event set up to celebrate the completion of the research and answer questions that may arise from the research. My plan is to host the meeting in my classroom on a Thursday evening and provide refreshments. If the number of stakeholders interested in attending is greater than 30, I will move the meeting to the school cafeteria or auditorium. During this meeting, I will give a brief presentation and summary of the research results. Then, I will answer questions from parents, administrators, and colleagues. I will also ask student volunteers to speak about their experience or present their solutions to problems they encountered during problem-based learning. I will obtain parent consent for students that volunteer to present.

Additionally, other teachers around my district, state, or country could benefit from my action research process. Buss and Zambo (2014) claim that action researchers must be willing to share their findings with multiple stakeholders. Therefore, I plan to submit the process and results as a workshop for local or national conferences. The South Carolina and National Councils of Teachers of Mathematics both have a submission process for presentations of research. I will also submit a proposal to present my research through the Association for Educational Communications & Technology. The School District of Pali County also allows teachers to share their classroom experiences and classroom interventions on district professional development days.

Johnson and Christensen (2017) emphasize the importance of releasing findings to all who may be interested. I would gladly show other teachers how I set up problem-based learning in a flipped classroom instructional environment. It would be beneficial to have a discussion with teachers from my local context and beyond. Improving my intervention, problems, or instructional environment would help me move forward with improvement of my practice. Another way to share my findings, increase my possibility of receiving valuable feedback, and reach teachers outside my local setting would be to submit my research for publication in academic journals. I plan to submit my research to the following academic journals: Interdisciplinary Journal of Problem-Based Learning, Journal of Research on Technology in Education, International Journal of Educational Technology, International Journal of Instruction, and Journal of Education and Learning.

During each phase of my process for sharing findings above, I will maintain student identity security with pseudonyms. The only exception will be for student volunteers who present to parents, administrators, and colleagues at an after-school event. However, their parents will need to give consent to allow them to participate. Researchers, teachers, or colleagues who would like to view my research data or results will only be given data that has been edited to preserve anonymity. Data will be stored in physical and electronic files that are locked, until it is needed for sharing.

CHAPTER 4

ANALYSIS AND FINDINGS

The purpose of this action research was examining problem-based learning in a flipped classroom instructional environment and measuring its effect on students' motivation and achievement in Algebra 2 at Pali High School. This study addressed the following research questions: (1) What is the impact of problem-based learning in a flipped classroom instructional environment on students' motivation in mathematics?; (2) What is the impact of problem-based learning in a flipped classroom instructional environment on students' self-efficacy in mathematics?; (3) What is the impact of problem-based learning in a flipped classroom instructional environment on students' mathematics achievement on Systems of Equations and Quadratic Functions?; and (4) What are students' perceptions of problem-based learning in a flipped classroom instructional environment?

The purpose of this section is to compile the findings from quantitative and qualitative data sources. Then, analysis methods and results will be described. The section begins with a discussion of quantitative findings from the Diagnostic Test on Systems of Equations and Quadratic Functions and the Motivation in Mathematics Survey. Descriptive statistics and inferential statistics will be delineated for each quantitative data source. Then, there will be a discussion about the qualitative findings from observation notes, student journals, and the focus group interview. Data amounts, coding techniques, examples, and description of themes will be examined.

Quantitative Findings

Two quantitative data collection instruments were administered before and after the innovation. Descriptive statistics will be presented for each data source from each of their administrations. On the Motivation in Mathematics survey, further analysis will be completed on specific categories of motivation that were measured. Then, analysis will be completed using the inferential paired samples *t*-test. The goal is to ascertain if there was a significant difference in scores before and after the innovation. This analysis will be completed for both quantitative data sources.

Diagnostic Test on Systems of Equations and Quadratic Functions

Students completed a diagnostic test before and after the innovation (see Appendix D). The test was created through the standards-based questions on their online textbook, and students completed the test online. The diagnostic test was comprised of 35 items on Systems of Equations and Quadratic Functions. Systems of Equations were the first nine items, and the remaining 26 items were primarily Quadratic Functions. However, there were a few items within the remaining 26 items that connected both topics. The total possible score, including any partial credit, was 40 total points. Scores from the online textbook were exported into a Microsoft Excel document. After scores were exported to Excel, the statistical software JASP was utilized to obtain descriptive statistics and inferential statistics.

In order to obtain internal reliability for the diagnostic test, the question analysis was adjusted to a scale score. Incorrect question scores were replaced with a score of 0, partially correct question scores were replaced with a score of 1, and completely correct question scores were replaced with 2. The scaled scores were saved as a CSV file and opened in the statistical software JASP. Reliability statistics were calculated for the pretest and posttest, and are given in Table 4.1 below. McDonald's Omega was utilized due to test items containing multiple responses (Dunn, Baguley, & Brunsden, 2014). The pretest items initially did not return a McDonald's Omega, due to no variance on Items 9 and 18. After those items were removed, JASP returned a McDonald's Omega value of 0.74. The posttest items returned a McDonald's Omega value of 0.83. Both of these values were acceptable internal reliability coefficients (Adams & Lawrence, 2019).

Table 4.1 *Diagnostic Test Reliability Statistics*

Test Administration	**McDonald's ω**
Pretest (n = 22)	0.74
Posttest (n = 21)	0.83

Validity was established by the online textbook standard correlation and expert representatives from my school district. First, the items were directly aligned to South Carolina state standards through the textbook publisher Pearson. The standards for Systems of Equations and Quadratic Functions were selected and sample questions were utilized to build the test. Second, the math department chair from Pali High School examined the alignment of questions and standards. She agreed with the textbook and my selection of questions. Finally, the Director of Secondary Math Education for Pali County School District examined the test and aligned standards. She made a couple suggestions for standards that were assessed on eight separate items. I took her advisement and adjusted the alignment to standards that she suggested.

Descriptive statistics. The CSV file for pretest scores and posttest scores was submitted to analysis in JASP. Table 4.2 below gives the mean scores and standard deviations for both tests, as well as the means and standard deviations, and for the calculated difference between posttest and pretest. The mean for the pretest was 32.68 (*SD* = 12.87). Both the mean and the standard deviation increased for the posttest to 51.38 (*SD* = 16.24). Although the mean increased between pretest and posttest, the standard deviation increase also points to an increase in the variance among scores. The distribution plots provided in Figure 4.1 also display the more normal distribution for the posttest scores.

Table 4.2 *Diagnostic Test Descriptive Statistics (n = 22)*

Statistic	Pretest	Posttest	Difference
M	32.68	51.38	18.70
SD	12.87	16.24	18.47

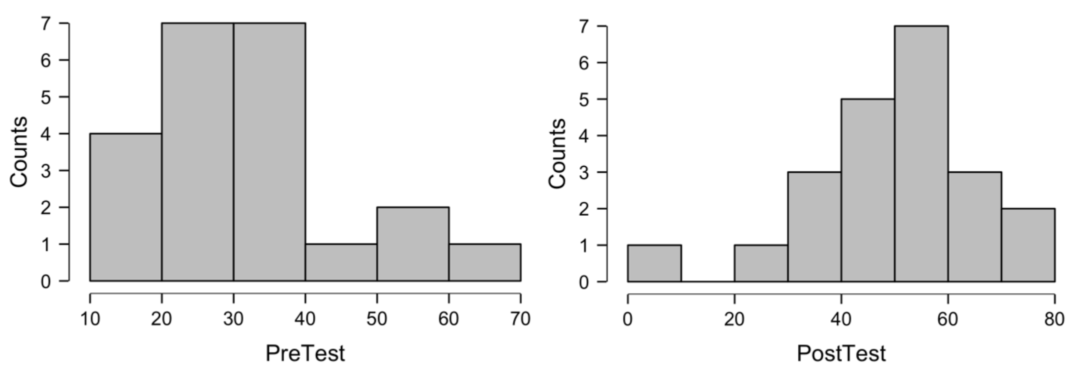


Figure 4.1 *Distribution Plots for Diagnostic Test Scores*

Inferential statistics. The CSV file for pretest and posttest scores was further analyzed in JASP utilizing a planned inferential paired samples *t*-test. This test was used to determine if there was a significant difference between pretest and posttest scores after the innovation (Adams & Lawrence, 2019). The Shapiro-Wilk test for normality was confirmed ($p = .212$). Therefore, a *t*-test was utilized as there was no significant deviation from normality (Adams & Lawrence, 2019). For the paired samples *t*-test, posttest scores were compared to pretest scores. The posttest mean scores were significantly higher than the pretest mean scores, $t(21) = 4.75$, $p < .001$, Cohen's $d = 1.01$. The effect size indicated a large effect by the innovation on achievement measured by the diagnostic test (Adams & Lawrence, 2019; Salkind, 2010).

Motivation in Mathematics Survey

Students completed a Motivation in Mathematics Survey before and after the innovation (see Appendix A). I crafted and renamed this survey by utilizing motivation items from the Academic Achievement and Motivation Survey by Jiang et al. (2018). The survey items spanned four subscales for a toal of 27 items: six items on *self-efficacy*, six items on *task value*, 12 items on *cost*, and three items on *positive classroom affect*. Students responded to items about these different motivational orientations on a seven-point Likert scale ranging from 1: *Not true at all of me* to 7: *Very true of me*.

For survey administration, items were placed in random order on a Google Form. Scores from the Google Form were exported into a Microsoft Excel document. In order to facilitate analysis, I placed data columns from each subscale of motivation together: self-efficacy, task value, cost, and positive classroom affect. Finally, the cost subscale motivation scores were reverse coded.

After all data were organized, I utilized the average function in Excel to calculate the overall motivation score for each student, as well as each subscale. These averages were completed for the preinnovation and postinnovation survey results. These overall motivation scores and motivation subscale scores were exported to a separate CSV document to make input into the statistical software JASP easier to read. For missing scores, I utilized a technique known by some researchers as personal mean score imputation (Peyre, Leplège, & Coste, 2011). Missing scores were replaced by the mean score of the subscale in which each question is located. After scores were exported, the statistical software JASP was utilized to calculate descriptive statistics and inferential statistics.

In order to obtain internal reliability for the Motivation in Mathematics Survey, all of the items scores were saved as a CSV file and opened in the statistical software JASP. Reliability statistics were calculated for overall motivation and each subcategory on the preinnovation and postinnovation measures. Results are presented in Table 4.3 below. The preinnovation measure returned a Cronbach's α value of 0.92 for overall motivation and the postinnovation measure returned a Cronbach's α value of 0.92. The following subscales were also examined for internal reliability on the preinnovation and postinnovation measures: self-efficacy, task value, cost, and positive classroom affect. For the pre-innovation measure, JASP returned Cronbach's α values of 0.92, 0.84, 0.81, and 0.79 respectively. For the post-innovation measure, JASP returned Cronbach's α values of 0.93, 0.85, 0.84, and 0.84. According to Adams and Lawrence (2019), all of these values were acceptable internal reliability coefficients.

Table 4.3 *Motivation in Mathematics Survey Reliability Statistics (n = 22)*

Subscale	**Preinnovation Cronbach's α**	**Postinnovation Cronbach's α**
Overall Motivation	0.92	0.92
Self-Efficacy	0.92	0.93
Task Value	0.84	0.85
Cost	0.81	0.84
Positive Classroom Affect	0.79	0.84

Descriptive statistics. The CSV files for preinnovation scores and postinnovation scores were submitted to analysis in JASP. Table 4.4 below gives the mean scores and standard deviations for preinnovation and postinnovation measures. The overall motivation mean for the preinnovation measure was 4.36 (*SD* = 0.93). The mean increased and standard deviation decreased for the postinnovation to 4.45 (*SD* = 0.77). For self-efficacy, the mean increased from 4.25 to 4.54, and the standard deviation decreased from 1.24 to 1.18. For task value, the mean increased from 4.67 to 4.94, and the standard deviation decreased from 1.28 to 1.08. The cost subscale was the only mean to decrease. The cost subscale mean decreased from 4.52 to 4.35, and the standard deviation decreased from 0.98 to 0.90. For positive classroom affect, the mean increased from 3.27 to 3.65, and the standard deviation decreased from 1.36 to 1.05. The spread between overall motivation scores and all subcategory scores decreased, as evidenced by the standard deviation scores decreasing.

Table 4.4 *Motivation in Mathematics Survey Descriptive Statistics (n = 22)*

Subscale	Preinnovation *M* (*SD*)	Postinnovation *M* (*SD*)
Overall Motivation	4.36 (0.93)	4.45 (0.77)
Self-Efficacy	4.25 (1.24)	4.54 (1.18)
Task Value	4.67 (1.28)	4.94 (1.08)
Cost	4.52 (0.98)	4.35 (0.90)
Positive Classroom Affect	3.27 (1.36)	3.65 (1.05)

Inferential statistics. The CSV file for preinnovation and postinnovation motivation scores was further analyzed in JASP utilizing a planned inferential paired samples *t*-test. This test was used to determine if there is a significant difference between preinnovation and postinnovation scores (Adams & Lawrence, 2019). The Shapiro-Wilk test for normality was performed and returned non-significant values for overall motivation (p = .377), self-efficacy (p = .050), task value (p = .898), cost (p = .745), and positive classroom affect (p = .558). Therefore, a t-test was utilized as there was no significant deviation from normality (Adams & Lawrence, 2019). For the paired samples t-test, postinnovation motivation scores were compared to preinnovation motivation scores. Due to performing multiple tests on the same data, I also utilized a Bonferroni correction to combat the possibility of a Type 1 error (Adams & Lawrence, 2019). I divided the significance level (α = 0.05) by the number of tests completed. The Bonferroni correction resulted in a new significance level of 0.01 (α / 5). The paired samples t-tests did not return a significant p-value for overall motivation or any subscale. The findings for the paired samples t-tests are presented in Table 4.5 below.

Table 4.5 *Paired Samples t-Tests for Motivation in Mathematics Survey*

Postinnovation – Preinnovation	***t***	***df***	***p***
Overall Motivation	0.91	21	.187
Self-Efficacy	1.69	21	.053
Task Value	1.44	21	.083
Cost	-1.18	21	.875
Positive Classroom Affect	1.40	21	.088

Qualitative Findings

In the following section, I will discuss the qualitative data sources that were gathered during my study. First, the quantity of each source will be given, as well as the number of codes associated with each source. Then, I will give the process of analysis for all of my qualitative data with examples. Finally, I will present the findings from code analysis and emergent themes.

Data Sources

Teacher observations. Throughout the research process, I kept an observation journal about all aspects of the innovation, and included reflexive notes intertwined with the observations. The journal began with general observations about my students' demographic backgrounds and recent experiences with digital learning. The remainder of the teacher observation journal spanned the innovation period from February 2 through April 5. Each day, including several weekends, I made observation notes about students participating in the innovation and reflexive notes about my experiences and perceptions during the innovation (see Figure 4.2). At the conclusion of the innovation, I transcribed the entire observation journal into a 12-page Word document for later analysis in Delve, an online software for analyzing qualitative data. Students' names were replaced with a pseudonym from a random name generator.

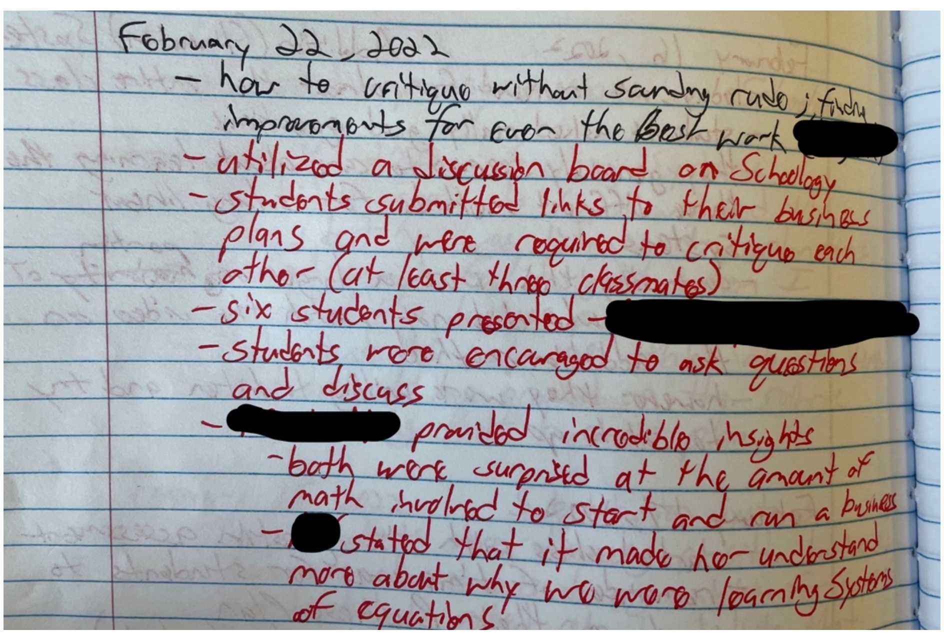


Figure 4.2 *Sample Observation Journal*

Student journals. My original plan was to have students complete journal entries every week. However, due to time constraints on students' workload and various interruptions of class time by school events, I decided to limit the number of journal entries. The journal prompts are provided in Appendix C. Journal prompts were given to students through a Google Form, due to email and password protection available through our district. After data were collected through the Google Form, it was exported by response into five Word documents. Students' names were replaced with pseudonyms from a random name generator. Students' participation for the journals was never 100%, but the amount of information totaled more than my own observation journal. Table 4.6 below gives the page yield and student participation level for each date. Responses varied from full paragraphs to bullet points to short phrases.

Table 4.6 *Student Journal Data Amounts*

Date	Page Yield	Student Participation
February 22	3 pages	11 out of 22 students
March 4	5 pages	21 out of 22 students
March 18	3 pages	11 out of 22 students
March 25	2 pages	8 out of 22 students
April 8	1 page	4 out of 22 students

Focus group interview. Six students were selected for the focus group interview that was conducted on April 14, 2022. During the interview, I also made observation notes in my research journal. The approximately 50-minute interview was recorded and transcribed verbatim. Notes were also made in my researcher's journal about crosstalk, laughter, and agreement statements, such as "*right*" or "*yep*". The transcription yielded a

28-page (14pt font) Word document. Timestamps were included, and students' names were replaced with pseudonyms from a random name generator.

Code associations. Most coding associated with teacher observations revolved around teacher perceptions, as that is primarily what observations and reflexive notes from the teacher provide. However, there were also connections made with codes on motivation and student perception as well. Most of the coding for students' journals and the focus group interview addressed students' perceptions of their motivation in mathematics and experiences of problem-based learning in a flipped classroom. Further coding focused on motivational constructs and emergent codes. Table 4.7 gives the number of codes associated with each data source. Overall, there were 46 codes utilized from predetermined codes and emergent codes.

Table 4.7 *Code Association with Data Sources*

Data Source	Number of Codes
Teacher Observations	44
February 22 Student Journal	37
March 4 Student Journal	31
March 18 Student Journal	33
March 25 Student Journal	33
April 8 Student Journal	29
Focus Group Interview	45

Analysis of Qualitative Data

The process that I used for my qualitative analysis was a general inductive approach, as encouraged by Liu (2016) and Thomas (2006). Liu (2016) suggested using a generic inductive approach when analysis does not fit neatly into qualitative approaches like phenomenology or grounded theory. I scrutinized my data through multiple cycles that are outlined below. This cyclical approach allowed me to examine emerging categories and themes, relate to previous theories, and refine my own analysis (Creswell, 2017; Saldaña, 2021; Tracy, 2020). I utilized the following four stages for my cyclical approach: (a) managing data and initial reading, (b) initial coding and emergent coding, (c) developing themes and evaluating interpretations, and (d) presenting findings. These stages are based on the stage approach outlined by Creswell (2017).

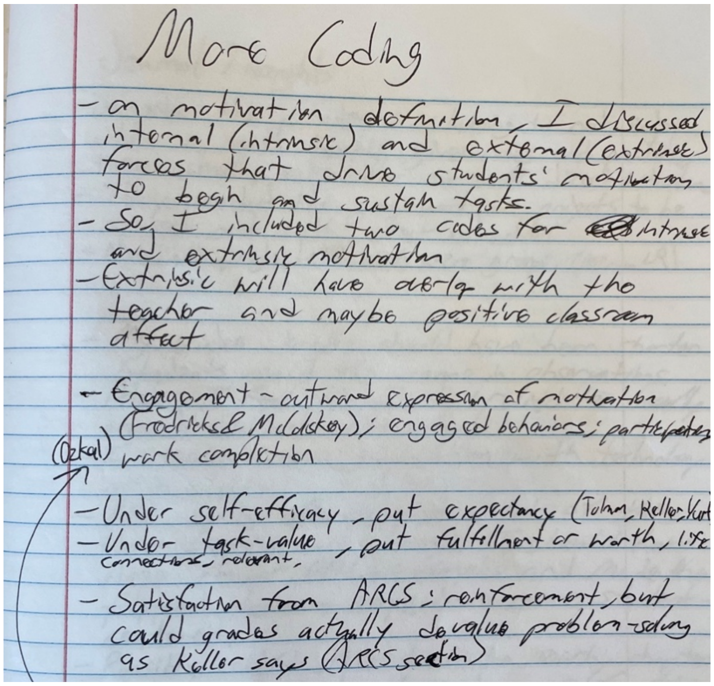
Managing data and initial reading. The initial stage in my qualitative analysis was to produce accurate transcriptions of the data. During this process, I also made sure that students' identities were protected by password-protected documents and randomly generated pseudonyms. Students' journal entries were exported and double-checked for accuracy and connection to correct pseudonyms. My observation journal was written by hand; therefore, I transcribed it by typing my observations verbatim into a Microsoft Word document. I utilized a downloaded transcription software, called Descript, to assist in speeding up the transcription of my focus group interview. However, due to dialect and accents, I listened and checked for accuracy. Accuracy checking allowed me to hear and consider the interview responses for a minimum of three times per response. During multiple sessions of listening to students' responses, I also made reflexive notes that would later lead to more codes.

My initial codes were the only portion of my process that was not completely inductive. My initial codes were grounded in my research on motivation, flipped classrooms, and problem-based learning (i.e., a priori codes). They were also related to my research questions. Table 4.8 gives a complete list of my initial codes. I utilized the categories from ARCS theory by Keller (1987), and I used the subscales from my Motivation in Mathematics Survey (Jiang et al., 2018). I also included general codes about flipped classrooms and problem-based learning. Most of these codes were what Saldaña (2021) has referred to as descriptive codes.

Table 4.8 *Initial Codes*

Codes	
attention	flipped classroom
relevance	teacher perspective of flipped classroom
confidence	student perspective of flipped classroom
satisfaction	problem-based learning
self-efficacy	teacher perspective of problem-based learning
task value	student perspective of problem-based learning
cost	extrinsic motivation
positive classroom affect	intrinsic motivation

After transcriptions were completed, my first cycle of reading began. During the first reading cycle, I did not code any of the data. My goal was to gain an overall perspective of the data before coding and to let my students' responses guide my emergent code creation. As I was reading, I made notes in my researcher's journal for how students' responses were possibly indicating emergent codes (see Figure 4.3), as well as subcodes for my a priori codes.



More Coding

- on motivation definition, I discussed internal (intrinsic) and external (extrinsic) forces that drive students' motivation to begin and sustain tasks.
- So, I included two codes for intrinsic and extrinsic motivation
- Extrinsic will have overlap with the teacher and maybe positive classroom affect

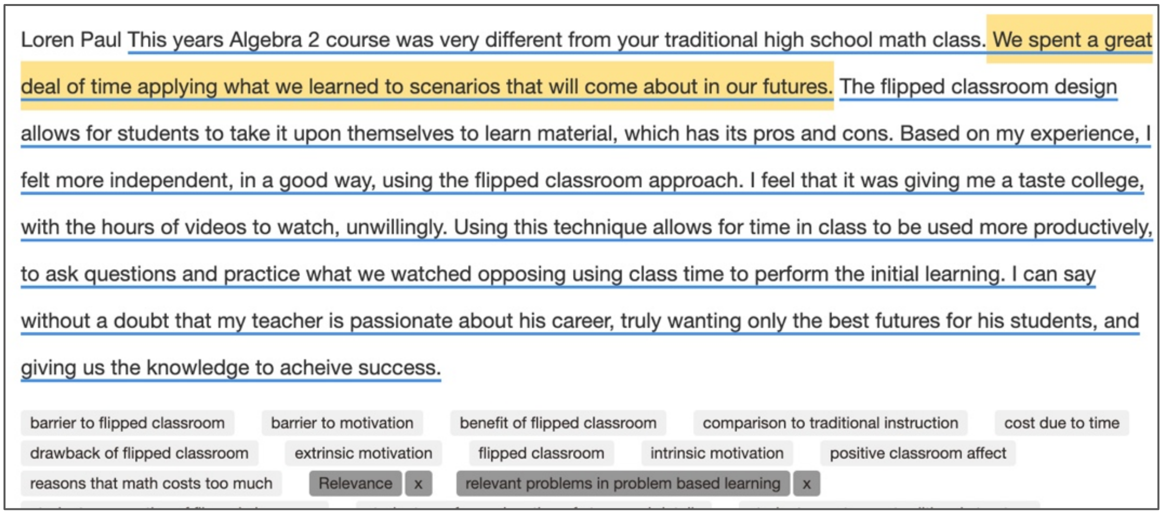
- Engagement - outward expression of motivation (Fredricks & McColskey); engaged behaviors; participation; work completion
(Ozkal)

- Under self-efficacy, put expectancy (Tohm, Keller, Kurt
- Under task-value, put fulfillment or worth, life connections, relevant,

- Satisfaction from ARCS; reinforcement, but could grades actually devalue problem-solving as Keller says (ARCS section)

Figure 4.3 *Additional Coding Notes From Observation Journal*

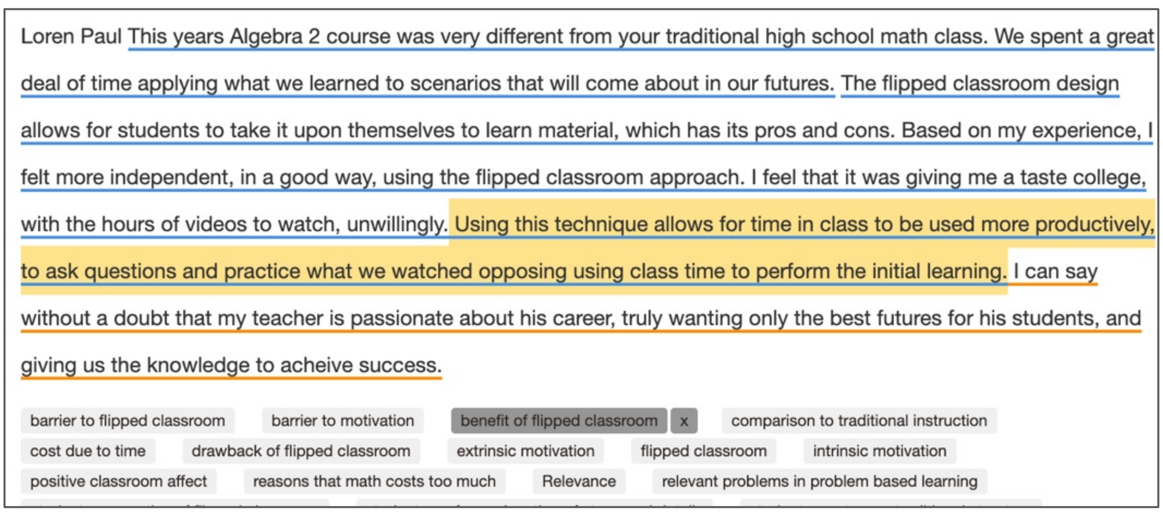
Initial coding and emergent coding. The next stage of my qualitative analysis was my initial coding round and emergent coding. During this stage, I completed two coding cycles for each data source. The initial coding process provided two additional times that I was able to read and analyze the data. For the coding process, I employed the online qualitative analysis tool Delve. I began the first coding cycle utilizing the a priori codes after input into Delve. Delve allowed for selection of phrases, sentences, or paragraphs. It also allowed coding each selection with multiple codes. As an example, one sentence of Loren's student journal was coded with *relevance* and *relevant problems in problem-based learning* (see Figure 4.4). Another portion of the response was coded with *benefit of a flipped classroom* (see Figure 4.5). In order to keep my data within context, I primarily coded complete sentences and paragraphs. I wanted to ensure that surrounding text was quickly accessible when I focused in on different codes during later analysis.



Loren Paul This years Algebra 2 course was very different from your traditional high school math class. We spent a great deal of time applying what we learned to scenarios that will come about in our futures. The flipped classroom design allows for students to take it upon themselves to learn material, which has its pros and cons. Based on my experience, I felt more independent, in a good way, using the flipped classroom approach. I feel that it was giving me a taste college, with the hours of videos to watch, unwillingly. Using this technique allows for time in class to be used more productively, to ask questions and practice what we watched opposing using class time to perform the initial learning. I can say without a doubt that my teacher is passionate about his career, truly wanting only the best futures for his students, and giving us the knowledge to acheive success.

barrier to flipped classroom | barrier to motivation | benefit of flipped classroom | comparison to traditional instruction | cost due to time | drawback of flipped classroom | extrinsic motivation | flipped classroom | intrinsic motivation | positive classroom affect | reasons that math costs too much | Relevance x | relevant problems in problem based learning x

Figure 4.4 *Initial Coding Example 1*



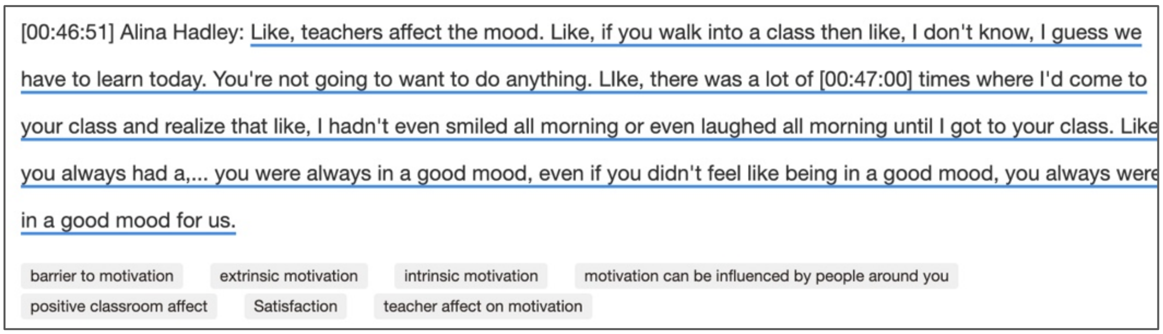
Loren Paul This years Algebra 2 course was very different from your traditional high school math class. We spent a great deal of time applying what we learned to scenarios that will come about in our futures. The flipped classroom design allows for students to take it upon themselves to learn material, which has its pros and cons. Based on my experience, I felt more independent, in a good way, using the flipped classroom approach. I feel that it was giving me a taste college, with the hours of videos to watch, unwillingly. Using this technique allows for time in class to be used more productively, to ask questions and practice what we watched opposing using class time to perform the initial learning. I can say without a doubt that my teacher is passionate about his career, truly wanting only the best futures for his students, and giving us the knowledge to acheive success.

barrier to flipped classroom | barrier to motivation | benefit of flipped classroom x | comparison to traditional instruction | cost due to time | drawback of flipped classroom | extrinsic motivation | flipped classroom | intrinsic motivation | positive classroom affect | reasons that math costs too much | Relevance | relevant problems in problem based learning

Figure 4.5 *Initial Coding Example 2*

While I was completing the first coding cycle, I also compared my analysis to my notes from the first stage. I examined my thoughts about emergent codes and subcategories of my a priori codes. My students' responses made it clear there were more codes to include. An example occurred during my analysis of my focus group interview. Students opened up about different positive or negative influences on their motivation. In addition, I was completing my quantitative analysis for my Motivation in

Mathematics Survey. There was no significant increase in motivation scores, and the cost subscale actually decreased on average for students. Therefore, I added several codes associated with motivation and the motivational constructs from the ARCS model and my Motivation in Mathematics Survey (Jiang et al., 2018; Keller, 1987). Below, Alina's response was coded for emergent codes like *barrier to motivation* and *teacher affect on motivation* (see Figure 4.6).


[00:46:51] Alina Hadley: Like, teachers affect the mood. Like, if you walk into a class then like, I don't know, I guess we have to learn today. You're not going to want to do anything. LIke, there was a lot of [00:47:00] times where I'd come to your class and realize that like, I hadn't even smiled all morning or even laughed all morning until I got to your class. Like you always had a,... you were always in a good mood, even if you didn't feel like being in a good mood, you always were in a good mood for us.

barrier to motivation
extrinsic motivation
intrinsic motivation
motivation can be influenced by people around you
positive classroom affect
Satisfaction
teacher affect on motivation

Figure 4.6 *Emergent Coding Example 1*

I continued the process of applying a priori codes and emerging codes for all data sources. Whenever I established a new emergent code, I would code it in the current data source that I was reading. In the subsequent cycle, I would return to previous data sources to code for emergent codes. Table 4.9 gives a list of emergent codes. Some of these emergent codes were subcategories of my a priori codes. Figure 4.7 highlights a small portion of nested codes on Delve.

Table 4.9 *Emergent Codes*

Codes	
barrier to motivation	cost due to time
student choice	motivation can be influenced by others
benefit of problem-based learning	teacher affect on motivation
drawback of problem-based learning	cost due to return on investment

Codes	
relevant problems in problem-based learning	students prefer explanation of steps and detail
problem solving techniques	cost due to lack of need
problem solving improvement	cost due to difficulty
barrier to flipped classroom	reasons that math costs too much
benefit of flipped classroom	student feelings about cost of Algebra 2
drawback of flipped classroom	

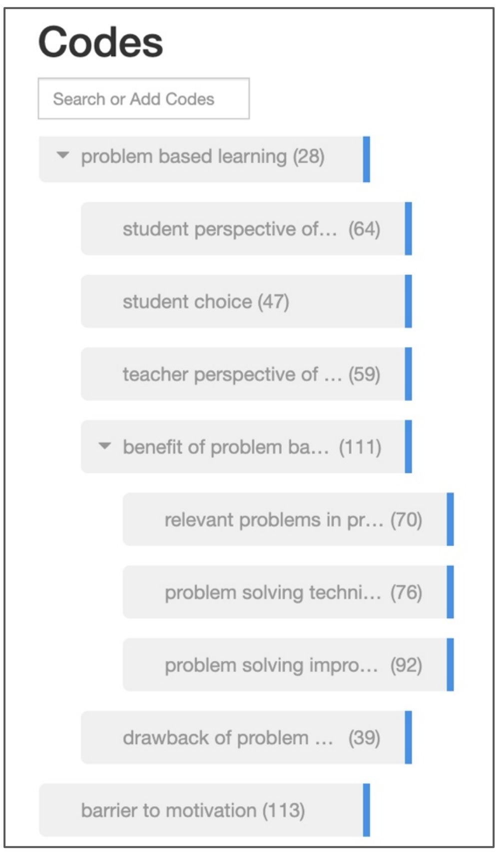


Figure 4.7 *Code Nesting in Delve*

After completing the initial coding cycle, I took a two-week break to prevent mental fatigue from clouding my judgement about current codes, further emergent codes, and themes that were already starting to formulate in my mind (Saldaña, 2021; Tracy, 2020). However, I did make notes of my current thoughts in my researcher's journal. Mertler (2019) also encourages regularly stepping back for introspection. Two particular frequent comments by my students were guiding construction of corresponding themes. Frequency alone does not indicate a theme, but it can help to solidify an argument for a theme (Saldaña, 2021). First, students pointed out their lack of motivation due to the time that was required to do math assignments or watch flipped videos. Second, students indicated how important teachers' attitudes and effort were to their motivation.

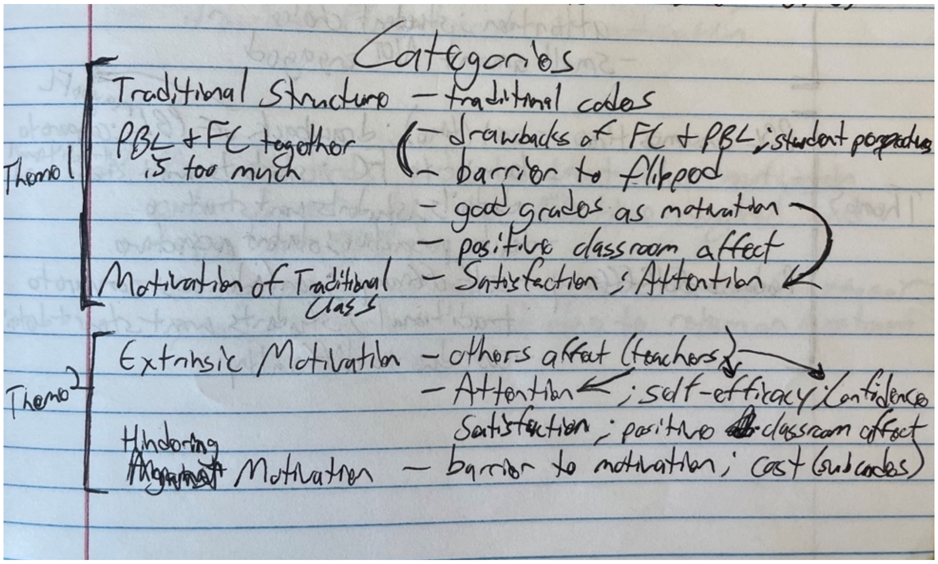
Later, I began another coding cycle, which constituted at least my fourth reading of all data sources. One priority was to return to data sources that were not coded for emergent codes during the first cycle of coding. Also, I continued to search for more emergent codes. During this coding cycle, I implemented a few *in vivo* codes that came directly from students' responses or paraphrasing students' responses (Saldaña, 2021). A third theme was also beginning to emerge that connected with the codes of *task value*, *relevance*, and *relevant problems in problem-based learning*. Students were participating in engaging activities that kept their attention and helped them develop real-world skills. Their skill development and engagement on high-value tasks was noted in my observation journal data source as well. Table 4.10 displays the final emergent codes that were added during this coding cycle. Delve also allowed me to rearrange codes into subcodes through a drag and drop feature.

Table 4.10 *Emergent Codes from Second Cycle*

Codes
math became easier
comparison to traditional instruction
students want more traditional structure

Codes
good grades as motivation
group work makes math more enjoyable
time of year affects motivation
engagement
students engaged in math
students engaged in problem-solving
students not engaged in problem-solving
students developing real-world skills

Developing themes and evaluating interpretations. After the completion of my coding cycles, the third stage of my analysis process involved the development of themes and evaluating my interpretations. My process during this stage was similar to focus coding, due to the fact that I scrutinized frequent and salient codes to create categories (Saldaña, 2021). I examined the codes and began to group codes into categories or make codes a category of their own. Due to the broad nature of several codes, there was overlap between themes. Therefore, I did not utilize the Delve rearrangement tool. Some categories utilized portions of data from the same codes. Instead, I made notes of categories in my research journal and what codes corresponded to those categories. Once categories were established, I grouped categories into an overarching theme. I examined the support for three themes that had already started to formulate during the coding process, as well as two other themes that developed. See Figure 4.8 and Figure 4.9 for examples of category and theme building. The figures are followed by a paragraph that describes an example process of theme development.



Categories

Theme 1

Traditional Structure – traditional codes

PBL + FC together is too much – drawbacks of FC + PBL; student perspectives

– barrier to flipped

– good grades as motivation

– positive classroom affect

Motivation of Traditional Class – Satisfaction; Attention

Theme 2

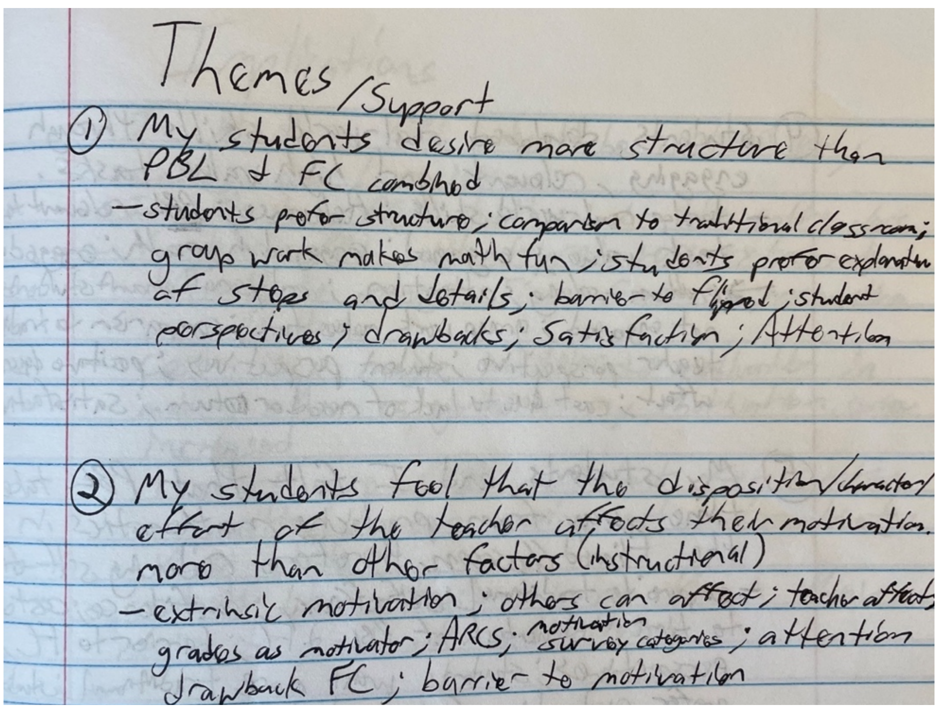
Extrinsic Motivation – others affect (teachers)

– Attention; self-efficacy; Confidence

Satisfaction; positive classroom affect

Hindering ~~Argument~~ Motivation – barrier to motivation; cost (subcodes)

Figure 4.8 *Category and Theme Building Notes*



Themes/Support

① My students desire more structure than PBL + FC combined

–students prefer structure; comparison to traditional classroom; group work makes math fun; students prefer explanation of steps and details; barrier to flipped; student perspectives; drawbacks; Satisfaction; Attention

② My students feel that the disposition/character effect of the teacher affects their motivation more than other factors (instructional)

–extrinsic motivation; others can affect; teacher affect; grades as motivator; ARCS; motivation survey categories; attention drawback FC; barrier to motivation

Figure 4.9 *Theme Formation and Category Support*

Due to my study's focus on motivation in mathematics, it was my desire to examine my students' responses about their motivation. I wanted to ascertain what motivated them and what hindered their motivation. Two categories were inherently created and further bolstered by my focus group interview experience. The first category began simply as *motivation*. Originally, it included the codes and subcodes of *intrinsic motivation* and *extrinsic motivation*. However, after analyzing the reflexive notes of my focus group interview and students' responses, this category was narrowed and given the title of *enablers of motivation*. Students did not indicate high levels of intrinsic motivation to succeed. Their external motivators included grades and group work during class, but those motivators were not as strongly emphasized. Students noted the importance of the teacher to their motivation. Within this category, I also included the codes of *attention*, *confidence*, *self-efficacy*, *satisfaction*, and *positive classroom affect*. Students pointed out how teachers can hinder motivation within those statements. This observation led to my second category of *barriers of motivation*. Included within this category were the codes of *barrier to motivation* and *cost* (with subcodes). Intertwined within the students' responses was a reiteration of how teachers can affect a students' reaction to this difficulty. Table 4.11 specifies the codes that contributed the evidence for two categories. Some codes, specifically those that dealt with motivational constructs, overlapped with other categories and other themes.

Table 4.11 *Codes to Categories Link*

Codes	**Category**
extrinsic motivation motivation can be influenced by others teacher affect on motivation attention confidence self-efficacy satisfaction positive classroom affect	Enablers of motivation

Codes	Category
barrier to motivation cost • cost due to return on investment • cost due to lack of need • cost due to difficulty • reasons that math costs too much • student feelings about cost of Algebra 2	Barriers of motivation

I continued the process of inspecting students' responses to determine if more categories or codes were necessary. I concluded that these insights from students provided a strong understanding of a prime influence in their motivations. Therefore, I established the following theme: The encouragement and effort of their teacher positively affected their motivation more than other factors.

Presenting findings. The final stage of my process was to present the findings of my themes. After analysis, I identified five themes:

Theme 1: Students desired more traditional structure than problem-based learning in a flipped classroom.

Theme 2: Problem-based learning was time consuming and prevented practicing math skills.

Theme 3: The encouragement and effort of their teacher positively affected their motivation more than other factors.

Theme 4: Motivation was lower due to time required and time of the school year.

Theme 5: Students developed real-world skills through engaging, relevant, and high value tasks.

Each theme is discussed in the following section. Support from data and research is also included.

Presentation of Findings

Qualitative data were obtained from a teacher observation journal, five separate student journals, and a focus group interview with six students. All data sources were transcribed verbatim from the original voice of the students or teacher. The observation journal consisted of my own observations and notes. The student journals and focus group interview were direct spoken or written quotes from students' responses. All names were replaced with pseudonyms from a random name generator. Five themes emerged during qualitative analysis. Table 4.12 provides a summary of themes and categories. In the following sections, I will present and interpret my themes and categories.

Table 4.12 *Theme and Category Summary*

Themes	**Categories**
1. Students desired more traditional structure than problem-based learning in a flipped classroom.	• Students desired traditional structure for instruction • Combining problem-based learning and the flipped classroom was too much
2. Problem-based learning was time consuming and prevented practicing math skills.	• Problem-based learning consumed too much time • Problem-based learning reduced math understanding
3. The encouragement and effort of their teacher positively affected their motivation more than other factors.	• Enablers of motivation • Barriers of motivation

Themes	Categories
4. Motivation was lower due to time required and time of the school year.	• Cost of math • Lack of intrinsic motivation
5. Students developed real-world skills through engaging, relevant, and high value tasks.	• Engagement • Relevance • Task-value

Theme 1: Students desired more traditional structure than problem-based learning in a flipped classroom.

In this study, traditional instruction was defined as lecture or direct instruction to deliver mathematics content (Magliaro et al., 2005; Markušić & Sabljić, 2019). Problem-based learning was defined as instruction that was facilitated by ill-structured, real-world scenarios with open-ended solutions or application of Algebra 2 concepts that students can discover (Barrows & Tamblyn, 1980; Hmelo-Silver, 2004). The flipped classroom was defined as students receiving primary instruction at home and practice during in-person school time (Eppard & Rochdi, 2017). An aspect of this study was to explore students' perceptions of utilizing a hybrid of nontraditional instructional methods. Combining multiple forms of instruction became problematic for students. While students were experiencing the benefits of solving real-world problems, they were still concerned about their knowledge of Algebra 2. This conflict led students to desire a return to traditional math instruction.

My students indicated that real-world problems in a flipped classroom could not sustain their attention. Keller (1987) has pointed out that attention must not only be gained but sustained to motivate students in classrooms. Researchers have indicated that real-world problems can make math classes more interesting for students and capture their attention (Akers, 2017; Le Roux, 2008; Meredith, 2015). However, the novelty of a new instructional method can dissipate (Meredith, 2015). Ghufron and Ermawati (2018) noted that students still wanted clear instruction— even within problem-based learning. My students also mentioned the desire to have clear steps and details versus the freedom to create their own solutions and presentations. Finally, Fukuzawa et al. (2017) noted that some students expressed they were not actually learning the course material during non-traditional instruction. Often, my students agreed.

Students' responses gave evidence for their desires to maintain a more traditional structure for instruction. The responses necessitated creation of emergent codes that directly related to students' perceptions about problem-based learning in a flipped classroom. Thus, Theme One stems directly from students' experiences and their own words. Theme One findings were established with two supporting categories: (a) Students desired traditional structure for instruction and (b) Combining problem-based learning and the flipped classroom was too much.

Students desired traditional structure for instruction. Traditional instruction does not involve problem-based learning or a flipped classroom. Students reacted to the change in instructional design for my Algebra 2 course by indicating their desires to have more traditional structure to their instruction. Students specified that learning through real-world problems was new and exciting, but they were afraid that the flipped classroom was not helping them learn course material. My students' perceptions corroborated past research. The perceptions of a novelty affect were also noted in research by Le Roux (2008) and Meredith (2015), and the fear of not learning course material was noted by Fukuzawa et al. (2017).

Students longed for the detailed steps of traditional instruction, even though they were participating in intentionally ill-structured problem-based learning. For each problem-based learning experience, students were given a central question that could be resolved in a variety of ways. There was never a single correct solution or process, and students were tasked with describing and defending their solution process for each problem. For example, the Business Plan PBL challenged students with, "What type of business would you start in your home town, and why? Create a business plan that would earn a bank loan for your business." Students were encouraged to be creative with their medium of presentation. During our first problem-based learning experience, the Business Plan PBL, I recorded an observation in my journal:

> When I asked students about this, the students indicated that they would rather be told exactly how to write and present. They wanted clear guidelines that were the same for everyone. I reminded them that this wouldn't happen in the real world (February 23, 2022).

Due to the Business Plan PBL being our first problem-based learning experience, I thought that students were displaying difficulty in adjusting to a different instructional design. However, students were beginning to show their preferences of instructional methods. During the Investment PBL, I made the following observation in my journal: "Students were very frustrated with me not giving them more information or telling them exactly what to do with the $10,000 [initial investment]" (March 31, 2022). Students wanted a formula or steps to follow, instead of creating their own, and students wanted their teacher to tell them how to do math versus discovering complex concepts.

Similarly, during the early stages of the innovation, I recorded a student's reaction to a problem that required her independent discovery of mathematical concepts. Catherin Klyment stated, "You know I don't like this." I asked, "Would you rather me teach it to you with notes?" She said, "Yes." Catherin was more vocal, but her sentiment was shared by others that began nodding heads. This reaction became a common occurrence as students pointed out their desire to have steps and details explained to them. During the focus group interview, Antonia Teagan further echoed the sentiment from earlier in the innovation, "Because like, you teach it, I get it. When I have to do it myself, I just, I don't know what it is." From the beginning of the innovation to the end, students pointed out their displeasure with the innovation's forms of instruction in mathematics.

For the flipped classroom, my students were asked to watch a lesson video at home. Then, we practiced the content and skills during the following class. This setup allowed me to provide more individual attention and feedback. However, some students were more direct in their description of sentiments towards the change in instructional style. In a response to one of the final student journals prompts, Kristiana Jeppe clearly stated, "I like the traditional better than the flipped classroom." Kristiana's desire was simple but direct to the core of this category: She preferred more traditional instruction. Similarly, during the focus group interview, Catherin Klyment echoed the sentiment, "I feel like it might've been easier for some of us, if you liked [sic] did one unit like flipped and the next one, like do your lesson in class." Even though Catherin did allow for the inclusion of flipped lessons, her expression about problem-based learning also indicated that she preferred traditional instruction. When discussing the transition from problem-based learning in a flipped classroom back to more traditional math instruction, Aleksandra Murali gave a more nuanced answer:

> I didn't really like the flipped classroom because I don't have time after school to watch 50- to 60-minute lessons. I thought that the problem-based learning was fun. It was good to have a different approach on math. I am glad that we are going back to traditional math instruction. I like the fact that when you teach in class I can ask questions as your teaching it instead of trying to remember the questions I had, and having to ask them during practice time.

Students felt that traditional instruction provided them more opportunities to learn the course topics and ask for help on topics that they did not understand.

Combining problem-based learning and the flipped classroom was too much. As part of the flipped classroom instruction, students were asked to watch lesson videos at home and practice the concepts and skills at the beginning of the following class. Remaining class time was utilized for students to solve their problem-based learning experiences. For most of the innovation, 50 to 75% of an 80-minute class period was used for problem-based learning. Students expressed their concerns on how much time was expended using the combination of instructional methods. Problem-based learning in a flipped classroom was a challenge to the traditional structure and was overwhelming students. The combination of two different methods was limiting the effect that each could have on its own. Students' focus on problem-based learning was interfering with their viewing of videos and productive practice in class. Their concern with trying to catch up with math content was limiting their exploration and creativity in solving techniques for problem-based learning.

During the middle of the innovation, students completed a journal entry which asked them to describe their experience of problem-based learning in a flipped classroom. In reference to this week of the experience, Lan Risto proclaimed, “I feel like this week in math was kinda [sic] challenging.” Lan was not a student that was typically willing to admit if something was challenging for him. His candid reply drew my attention to the fact that students were experiencing difficulty with the combination of instructional methods. During the focus group interview, Antonia Teagan was discussing the flipped videos in the context of a busy schedule. Antonia said, “But I will say there were days where I didn't do, I didn't watch them. Not because I didn't want to, or I was lazy. I was just really like, like, I just, was so tired that I got home ate and went to bed.” The work load combination became too much for students like Antonia. She was not able to focus on just one content area for math. I asked the participants in the focus group interview to think about the comparison between the innovation and traditional instruction. All six students said that it was different and nodded their heads when I asked if it pulled them out of their comfort zone. The new instructional design challenged students and could be the reason that many longed for traditional structure again.

Additionally, the combination of multiple instructional styles could have been counteracting benefits of each method. As I was about to give students an assessment on their Quadratics unit, they came to class with a concerning request. Problem-based learning builds students problem-solving skills (Fukuzawa et al., 2017; Ghufron & Ermawati, 2018; Soderstrom & Bjork, 2015), but I observed the following in my journal:

> Several students asked me to do more word problems (applications). This was very concerning to me, because I have been able to do more applications with this group than previous school years. The Flipped Classroom allowed more time for applications practice. Maybe, I should have focused even more than I did. One benefit from PBL is supposed to be better problem-solving skills… My fear is an incomplete understanding, due to the time used on problem-based learning (March 28, 2022).

It bothered me that the two instructional methods could be working against each other. Later, I also made a note expressing my concern about combining the flipped classroom with problem-based learning and hindering practice of math skills. Further, I noted that I would like to try problem-based learning without the pressure of completing a flipped unit on the side. Ghufron and Ermawati (2018) also noted the need for teachers to be able to manage time with problem-based learning.

Students also noticed the conflict in their own work. Additionally, they wanted to bring structure back to a more traditional math classroom. This perception was shared by several participants in my focus group interview. When asked about their experience during the innovation, Miriam Fatema stated, "Personally, I kind of struggled with confidence in the flipped schedule." Miriam is another student that did not struggle during traditional instruction. Often, I observed that she was overwhelmed by the combination of instructional methods. It should be noted that her grades did not suffer as much as she may claim. She was a student that held herself to a very high standard. In the focus group interview, Alina Hadley expressed her thoughts about the innovation:

> My opinion was like, on the video, so it was kind of hard to pay attention. So, if I was like more in the classroom, like you made jokes on the videos and stuff and like made it funny. Like in class you're like up yelling, running around, like we're all having fun.

The flipped videos did allow more time for practice in class and problem-based learning, but Alina pointed out that my direct instruction captured her attention more than the other methods. Alina specifically found her time limited due to work as well. Multiple instructional methods with a limited amount of time made her appeal for more traditional instruction. Students also requested more traditional instruction as the combination of the two instructional methods interfered with their performance. In a student journal entry, Catherin Klyment had the following response to problem-based learning in a flipped classroom, “I feel like we need to do more practice sheets and/or note sheets to have a better example…” Catherin was concerned with her grade and thought that the combination of instructional methods was hindering her progress. At the beginning of the class, most of the students argued on a student survey that traditional math instruction was boring and worksheets were not fun. They wanted more activities, but the combination of problem-based learning in the flipped classroom provided an overload of instructional techniques. Their response was to request a more traditional instructional approach.

Theme 2: Problem-based learning was time consuming and prevented practicing math skills.

Problem-based learning for my students included problems that required them to research solutions and processes to resolve real-world situations. The real-world problems included mathematical concepts but not direct lessons from the current units on Systems of Equations and Quadratic Functions. This instructional decision was in line with the suggestion by Galbraith (2012) to choose problems that promote mathematical understanding instead of contriving applications of equations. However, it also meant that students spent less time overall with Algebra 2 content, processes, and skills. Students did not like the effect that the extra time consumption had on practicing math skills. Students felt that problem-based learning was preventing their skills development, and they specifically asked for more practice.

Ghufron and Ermawati (2018) indicated that problem-based learning has required more time than a single traditional lesson. Facilitators of problem-based learning have been encouraged to guide students through a tutorial process that involved multiple steps (Barrows & Tamblyn, 1980; Hmelo-Silver, 2004). In this tutorial process, students identify facts, make hypotheses, and refine their solutions. Teachers act as a tutor to provide feedback and guide students with questioning techniques (Barrows & Tamblyn, 1980). This process does not lend itself to traditional skills teaching and assessment (Barrows & Tamblyn, 1980). Since my students were still being assessed on Algebra 2 skills, they observed that they spent skills practice time on problem-based learning instead of refining their math skills. Theme Two was established with two supporting categories: (a) Problem-based learning consumed too much time and (b) Problem-based learning reduced math understanding.

Problem-based learning consumed too much time. Originally, my plan for the innovation was to provide in-depth practice and enrichment at the beginning of each class on Algebra 2 skills from the flipped lesson videos. Then, the remainder of the class time was going to be utilized for problem-based learning experiences. I did not plan to spend more than half of the class on problem-based learning. However, students needed more guidance with the problem-based learning tutorial process than I previously assumed. Extra time on problem-based learning prevented students from being able to practice math skills for longer than 20 to 30 minutes in class. It also prevented me from providing additional time on feedback and correction for students' skills. For most of the innovation, 60 to 75% of an 80-minute class period was used for problem-based learning experiences. Even though students practiced previous skills at the beginning of each class, the majority of class time was spent on problem-based learning. In my observation journal, I noted my concern with the amount of time consumed by problem-based learning in a flipped classroom giving "less time to practice the math processes, content, and skills" (March 15, 2022). By design, problem-based learning does not include direct instruction of math skills, the flipped classroom design was intended to assist with more practice and feedback time as suggested by Amstelveen (2019). My students and I both noticed that time spent on problem-based learning was equivalent to time taken away from improving skills with Systems of Equations and Quadratic Functions.

Several students expressed concerns about the time that was needed by problem-based learning interfering with their math practice. After we had returned to traditional instruction, I gave students a final student journal prompt that asked students about their experience with problem-based learning in a flipped classroom and the return to traditional instruction. On the final journal prompt, Aleksandra Murali indicated:

> I am glad that we are going back to traditional math instruction. I like the fact that when you teach in class, I can ask questions as your [sic] teaching it instead of

> trying to remember the questions I had and having to ask them during practice time.

Aleksandra highlighted that math practice time was limited, and she observed this was due to previously not being under traditional instruction. Similarly, several students expressed their concerns about not taking class time to practice more word problems. Two students gave their thoughts during the focus group interview:

> Alina Hadley: Yeah, we really didn't do that many word problems.
>
> Lan Risto: I think if we did more [word problems], then, it'd be easier.

Both Alina and Lan pointed out the lack of time on word problems. Historically, my students have complained about word problems being the most difficult math problems they encountered. Students wanted to be successful in class and make good grades. Their perceived lack of practice time contributed to their belief that time spent on problem-based learning was the foundation of their difficulty with word problems and general math skills. Lack of time to practice weighed heavily on their desire for more traditional instruction from theme one as well.

Problem-based learning reduced math understanding. Students who expect to succeed in classes are more motivated to persevere, even when content becomes difficult (Keller, 1987; Yurt, 2015). Hwang (2016) stated that students who were confident in their ability to accomplish math tasks engaged in higher-level thinking and increased their achievement. Jiang et al. (2018) also point out that ability beliefs, like self-efficacy, are the strongest predictors of engagement and achievement. Due to the increased amount of time that was spent on problem-based learning in a flipped classroom, students lamented the lack of time for practicing math skills. Students' confidence in their math skills and self-efficacy at Algebra 2 waned. Confidence and self-efficacy are two motivational constructs that are very closely related and essential to increased achievement (Hwang, 2016; Jiang et al., 2018). Miriam Fatema indicated a "lack of confidence," due to insufficient practice. For students, confidence meant their ability or effort being enough to affect achievement on math skills. Miriam did not even think it would be beneficial to attempt the math. In their student journals about problem-based learning, students discussed their perceptions about this new style of math instruction. Lan Risto proclaimed, "It was easier than a normal class," but Stefan Hari stated, "I do not understand the math." Lan indicated his perception that problem-based learning was easier than normal math class, and other students expressed similar sentiment. However, Stefan pointed to his internal belief that he did not understand the math. He did not believe that he could succeed. While Stefan did not mention self-efficacy directly, he spoke of his lack of belief that he had the ability to do math. He meant that he did not believe in his own abilities affecting his achievement. In my analysis, I coded these statements as self-efficacy, due to agreement with Jiang et al.'s (2018) definition of self-efficacy. Students expressed that math understanding was not a key part of problem-based learning. Therefore, students attributed their inadequate math skills to the problem-based learning experience stealing time from practice on math skills.

As a teacher who placed a lot of emphasis on making sure students receive instruction and practice with math skills, it was obvious to me that problem-based learning was consuming some of the in-person instruction and practice. However, I still saw benefits that were gained from problem-based learning. In a response to a student journal prompt, Yasmin Nabuko said, "I had more fun than usually [sic] in math class because we are doing stuff and not only focusing on math." Yasmin was aware that our class was more interesting with problem-based learning, but she also noted that there was not a complete focus on math skills. In another journal entry discussing that week's class, Kristiana Jeppe stated, "Math class was fun this week, because we got to work in groups, and design an app." Again, my students were noticing the problem-based learning that we were experiencing, but not the math skills.

Due to reduced practice time and parallel decrease in confidence and self-efficacy, students indicated their math understanding had also decreased. During the focus group interview, several students expressed their lack of confidence in their ability do math. Antonia Teagan stated, "I guess, because like you teach it, I get it. When I have to do it myself, I just, I don't know what it is." Antonia lamented its effect on her understanding and ability to do math on her own. Similarly, Miriam Fatema said:

> I would understand it when you were doing it, and I would write down everything and I knew. But then it would come to the test, and I'd be like, shoot. I don't know what's going on. Like, I've done this, multiple times. Now, what? And I feel like maybe a lack of confidence came from that.

Miriam was also concerned with her confidence on the math. Students did not feel that their effort or ability was going to be enough to affect their achievement. Problem-based learning reduced the amount of time that I was able to provide instruction or feedback in-person.

As I continued to ask students about the innovation's impact on the categories of the ARCS model, students indicated their lack of self-efficacy, which they expressed negatively affected their math understanding. In the focus group interview, Antonia

Teagan proclaimed, "Like, I was just clueless. Had no idea what I was doing. It was like reading another language. I just don't understand what I was doing." Students, like Antonia, did not believe that they would succeed. Antonia was not a student who regularly complained about her lack of understanding. She was normally a highly motivated student who had actually learned a secondary language. Her comparison of math to another language further confirmed that students thought problem-based learning reduced their math understanding.

Furthermore, students were not the only participants to note the reduced math understanding. In my observation journal, I noted my concerns with students' understanding as well. In the middle of the innovation, I made the following observation:

> Several students asked me to do more word problems (applications). This was very concerning to me, because I have been able to do more applications with this group than previous school years. The flipped classroom allowed more time for applications practice. Maybe I should have focused even more than I did. One benefit from PBL is supposed to be better problem-solving skills (March 28, 2022).

Although word problems do tend to be more difficult for Algebra 2 students, I was very concerned that students were still struggling with the math. I also stated in my observation journal, "Students were very worried about their Quadratics Test when they came into the classroom today… I like PBL, but I am not sure how well it translates to Algebra 2 topics" (March 25, 2022). In my observation, problem-based learning was not an issue. Students learned to solve problems in a real-world context. My concern was the reduced understanding of Algebra 2 skills. I indicated my concern further in my observation journal, “My fear is an incomplete understanding, due to the time used on problem-based learning” (March 25, 2022). Again, I made a direct reference to the time component of problem-based learning. My observations agreed with the students’ statements. Problem-based learning consumed too much time that was normally spent on reviewing and reinforcing math skills. Because students were not directly or overtly practicing Systems of Equations and Quadratic Functions, they indicated a decline in confidence and self-efficacy on those math skills. Therefore, students expressed that time consumed by problem-based learning was leading to a reduction in their math understanding.

Theme 3: The encouragement and effort of their teacher positively affected their motivation more than other factors.

During interactions with students, particularly their answers during the focus group interview, students pointed out the importance of their teacher as an important factor to their motivation in math. Due to my study’s focus on motivation in mathematics, I wanted to examine my students’ responses related to their motivation. I wanted to ascertain what encouraged their motivation and what hindered their motivation. Motivation can have internal and external loci of control (Hornstra et al., 2018). In my analysis, I focused on students’ comments that specified motivating factors. Students’ journal responses and responses during the focus group interview suggested extrinsic motivating factors as their prime motivators, or inhibitors of motivation. Students did not indicate high levels of intrinsic motivation to succeed. Their extrinsic motivators included grades and group work during class, but those motivators were not as strongly emphasized. Students noted the significant impact of their teacher on their motivation.

This observation agreed with the assertion by Hornstra et al. (2018) that teachers' praise can instill belief in students that they are competent at completing tasks. In research, encouraging and supportive teachers were perceived as extrinsic motivators for students (Nenthien & Loima, 2016; Yurt, 2015).

Additionally, students pointed out that motivation could be hindered by bad teachers. Branom (2013) also agreed that classroom climates set by teachers have effects on motivation. Statements from my students and this research led me to examine hindrances to motivation in student responses as well. Personal motivational beliefs, prior academic achievement, and personal academic goals can affect students motivation (Patrick et al., 2007). Theme Three was established with two supporting categories: (a) enablers of motivation and (b) barriers of motivation.

Enablers of motivation. Enablers of motivation were defined as components that students indicated as encouraging their motivation in math class. Grades were mentioned around 48 times as a motivator, but teachers were mentioned twice as much. In a student journal entry about math class for the semester, Kristiana Jeppe stated, "I have to try a lot to have good grades." Good grades were a motivating influence for Kristiana to begin and sustain her effort in class. In other students' journal entries, working in groups, communicating with classmates, and doing activities instead of direct instruction were mentioned as motivators. In an early journal entry, Loren Paul said, "Math class was more enjoyable this week because we incorporated more group work, but not only that, it seemed as though the whole class talked to each other while presenting our business plans as we gave and received feedback on our work." Loren indicated that group work and discussion were aspects that brought enjoyment. In their responses to the beginning of the semester survey, my students indicated that fun math classes kept them engaged. Fredricks and McColskey (2012) pointed out that engagement was an outward display of students' motivation. When Loren stated that class was more enjoyable, she was indicating that she was more motivated to participate and complete work. When asked about their overall experience during the semester, Yasmin Nabuko stated in her journal entry, "I had more fun than usually [sic] in math class because we are doing stuff and not only focusing on math." Yasmin equated activities with fun in math classes and "focusing on math" to a negative side of normal math classes.

On the final two problem-based learning experiences, I decided to approach the introduction of the problem to the students differently. Typically, students are concerned with what kind of grade they will receive. I wanted to see if their motivation for doing problem assignments had changed. I did not let them know if they were going to receive a grade, and I was going to see if their motivation to solve the problem could come from within. Intrinsic motivation can motivate students to engage in activities for the pleasurable experience (Hornstra et al., 2018). The Consumer Sales PBL asked students to determine: In a potato chip variety pack, how many of each type of chip would you include? I made the following observation in my journal on the day that students participated in the Consumer Sales PBL:

> Today, I tried a different approach [to introducing a PBL]. I did not even mention a grade to the students. I wanted to see if their motivation to problem solve had changed. To my surprise, students started solving immediately. There was no hesitation. There were no students asking "Is this a grade?" or "How much is this

> worth?" I was very excited to see students engage in a problem-solving process without being forced or externally motivated (March 30, 2022).

My goal was to ascertain whether students could be motivated by internal drive versus grades. As evidenced by my observation notes, I was not very optimistic. I was surprised that students began working immediately. This observation reinforced that students could be motivated by something else, instead of grades. Active participation can be an indicator that students are motivated by the lesson's value and expectancy to succeed (Ahmed, 2017; Yurt, 2015).

As I read through students' responses on journal entries, it became clear that students were often motivated by working with others and motivated by the influence of others. In their study, Mirza and Hussain (2014) had students who were more motivated to by collaborative learning. In the first journal entry, Abraham Pyry said he got closer to perfecting skills and results through "beneficial evaluation from others." Those around him provided him the feedback that pushed him to better work. Abraham meant that his motivation to improve was enabled by classmates' assistance. After students had created a hypothetical phone application in groups, several of them responded to a journal entry with excitement about working with others. Kristiana Jeppe, Lan Risto, Wally Vratislav, and Annie Bram all described math class as fun or interesting. Kristiana and Lan attributed their excitement to, "we got to work in groups" and others responded with similarly worded sentiment. Students were enjoying working and participating in math class. Jiang et al. (2018) point out that a positive classroom experience can influence motivation in students. The classroom environment that was created by problem-based learning was encouraging students to be motivated to work. During the focus group interview, Miriam Fatema declared, “Because personally, if I'm surrounded by, like, determined courageous people, like I'm a hundred percent more motivated than I was 10 seconds ago.” Miriam pointed out that she perceived an increase in her own motivation when surrounded by people determined to succeed. Determined people enabled Miriam’s motivation in math class.

Throughout the students’ journal entries, they indicated that the innovation had influenced their feelings about math and its usefulness. However, they did not separate the instructional method from the instructor. Students viewed the flipped classroom and problem-based learning as my method, but considered me the most important component. In the final journal entry, Loren Paul said “I can say without a doubt that my teacher is passionate about his career, truly wanting only the best futures for his students, and giving us the knowledge to achieve success.” Loren viewed me, not the instructional method, as a source for knowledge and motivation to succeed. Students in the focus group interview further confirmed that their teachers have more influence on their motivation in math than other classmates, grades, instructional methods, or other aspects. During the focus group interview, Alina Hadley said “Teachers affect the mood. Like, if you walk into a class then like, I don't know, I guess we have to learn today. You're not going to want to do anything.” Alina indicated that a teacher’s disposition towards learning can motivate students to engage in math class. If students saw learning as a mandate from the teacher, instead of a passionate teacher that enjoyed learning, they did not want to work. Alina explained in further detail:

> I feel like I was more motivated because like, like you said, it goes back to we were talking about how the teacher also has to be motivated to teach you. Like,

> you would talk about how you would only be getting like an hour and a half, two hours sleep and come in and your mood wouldn't change. You would teach us to your full potential every day.

In spite of any difficulties or hindrances in my own life, Alina realized that I was passionate about her learning and doing everything within my ability to affect their motivation to learn math. My drive and passion for math affected her motivation to work in math class.

Other students in the focus group interview also noted that my effort and encouragement meant more to them than other influences on their motivation. Catherin Klyment discussed her daily experiences or home environment affecting her motivation and concluded:

> You just never know what's going on outside of school. And like, with that teacher being there, actually motivated, can change your whole attitude that day. Like, you can come in really exhausted and everything. And then after that class, you're like, yeah, I can do this. I've got this.

Catherin realized that external components can affect her motivation to actually engage, sustain effort, and succeed in math class. She discussed that teachers often dismiss students' behaviors without regarding the influences of home, grades, or students just having a bad day. She also stated that teachers could influence students' attitudes towards math by being motivated, in spite of other external influences on motivation. Miriam Fatema also agreed with her response during the focus group interview. She stated, "you and my first algebra teacher are the only math teachers I've ever had that are actually like putting in the effort and you can see it and it shows. And, our motivation is there too." Similar to Catherin and Alina's responses, Miriam connected her motivation to the effort and disposition of her teachers. She even noted that a previous teacher had the same effect on her motivation. Kiefer et al. (2015) also studied teacher support and found student motivation increases. Students were aware that various external elements enabled their motivation in math class. However, the influence of the teacher was the component that kept them motivated to begin and sustain effort in math class.

Barriers of motivation. Barriers of motivation were components that students indicated were inhibitors of their motivation in math class. When I analyzed the student journal and focus group interview responses, students expressed primarily external components that inhibited their motivation. During the focus group interview, Stefan Hari stated "I guess I came in overly confident because of geometry. I did really good in geometry, and then just, just lost it." Even though confidence is an internal belief, Stefan's confidence stemmed from an external stimulus of good grades in a previous math course. Instilling confidence in a student is a technique that should enable student motivation (Keller, 1987). However, Stefan claimed that his confidence led him to not work as hard. His overconfidence inhibited his motivation to begin and sustain effort to learn Algebra 2 math skills. At the beginning of the Flipped Classroom experience, Stefan immediately rebelled and told me that he would not watch any videos. His statement above was the realization that he had not learned the math skills because of his overconfidence.

In the final student journal entry, Aleksandra Murali expressed the barrier to her motivation was, "I feel like my motivation has decreased slightly due to spring break coming up. I am ready for a break however, I don't think that the different instruction has affected my motivation." Aleksandra indicated that an impending break from school was influencing her motivation in a negative way. From her second statement, she also specified that the instructional method did not affect her motivation. However, there is a possibility that one component was influencing another as well. During the focus group interview, Lan Risto and Antonia Teagan also expressed the same sentiments in two separate responses. Lan stated that problem-based learning in a flipped classroom would not motivate him at certain periods of the school year, because "I know if we had to do it at home and it's this close to spring break, I wouldn't do it." Lan meant that the time of year was a barrier to his motivation. Antonia stated in reference to the different instructional methods, "I was just upset that it was changed just because, one, I don't like change." Antonia implied that her resistance to change was a barrier to her motivation under different instructional methods.

Along with previously mentioned external influences on motivation, students' responses also identified the teacher as a major influence. According to students' responses, teachers could also become a barrier to motivation in math classes. During the focus group interview Catherin Klyment detailed:

> Cause sometimes you get teachers that are strict, like, do this, go home, do this, go through textbook. It's all there. I don't care. No, not helping you. Sorry. I'm busy. No, you can come after school. Some of us don't have time to come after school.

When I listened to this recording multiple times on the focus group interview, I heard the disdain and frustration in Catherin's voice. It was evident that Catherin expected her teachers to be an integral part of motivating her to learn. However, her experiences with teachers did not always motivate her. She indicated that some teachers did not give the effort that supported her motivation in class. They thought that the textbook was enough.

During the focus group interview, I adjusted my questioning to examine the aspect of a teachers affecting motivation. I asked students to expound upon how teachers affect their motivation. Students indicated another component where teachers of math can become a barrier to students' motivation. Catherin Klyment stated, "Like, how you grade the test, you'll give us a point or take one point off for some tiny mistake. Not the whole thing's wrong." Antonia Teagan interrupted with further confirmation, "I know a lot of teachers are like, oh, you get it wrong … But they don't, some teachers don't see how much you put … how much you work on it." Catherin and Antonia both referred to my practice of giving students partial credit for correct work completed on tests. Compared to other teachers, partial credit encouraged them to actually attempt problems that they normally would not attempt. It motivated them to strive through adversity in difficult problems and think about math. Catherin and Antonia both implied that teachers inhibited their motivation when they did not provide partial credit, reinforcing the theme that teachers affect motivation in math with their encouragement. They wanted teachers to encourage their effort in math. Kiefer et al. (2015) agree that teacher support can improve confidence, which in turn influences motivation to engage in current and future tasks (Nenthien & Loima, 2016; Skinner et al., 2008).

Theme 4: Motivation was lower due to time required and time of the school year.

As I read through students' responses to their journal prompts and responses to the focus group interview, they indicated that motivation was inhibited due to time required by math and the time period of the school year. The findings of this theme are based in the concept of cost being an inhibitor of motivation. For students, cost meant that class required too much time for them to commit to working on math. Students did not see math as a worthwhile activity in exchange for their time. Jiang et al. (2018) agree with rewards not matching the effort required, and define cost as "the negative consequences of engaging in a task" (p. 140). In contrast, pleasurable experiences can induce intrinsic motivation within students to engage in activities (Hornstra et al., 2018). Due to my study taking place in the spring semester, students were also very cognizant of their spring break that approached. Students' anticipation of spring break limited their drive to complete assignments and give full effort during class. Keller (1987) states that motivation can change and lack predictability. Skinner et al. (2008) also point out that students can lose their interest to participate over time. The time of school year was affecting my students' motivation in math class. Theme Four was established with two supporting categories: (a) cost of math and (b) lack of intrinsic motivation.

Cost of math. Students began the semester with an incorrect understanding of what Algebra 2 would require of their effort and time. I started the semester by telling students that Algebra 2 is a very different course from Algebra 1, but as usual students did not believe that I was being honest with them. During the focus group interview, Alina Hadley stated:

> That's what I think, yeah, I think a lot of us compared it to Algebra 1 and it was like, oh, it's just Algebra 1, but a little like leveled-up, so that's not going to be like, especially if you didn't struggle in algebra one, it's not going to be as time consuming everything. But, it's not like Algebra 1.

Alina indicated that she felt that Algebra 2 was just a leveled-up Algebra 1 course, and she thought that her time consumption would be similar. Her tone on her last line easily gave away her true feelings. Algebra 2 had surprised her with the amount of time that was needed to succeed. During the focus group interview, Lan Risto also agreed, “I think I underestimated it, how much time you have to put into it.” Again, Lan’s tone cannot be heard through a text quote, but he clearly was discouraged that Algebra 2 required more time than he was willing to give.

Students suggested that life outside of school is a major component that inhibits their motivation to expend the effort and time on math. Students indicated the length of my flipped classroom videos incurring a time cost as well. I recorded the following conversation in my observation journal when I announced the structure of problem-based learning in a flipped classroom:

> I explained how they would watch a video lesson at home, and we would practice and apply at school. Stefan Hari muttered under his breath, “I’m just not going to do it.” I replied, “Please don’t do this Stefan!” Stefan Hari stated, “I just don’t have time (February 11, 2022).

There were some students, like Stefan, who were already resistant to the cost that they would incur to do math and be successful. I wanted to get a little more information from Stefan, so I asked him more about this incident during the focus group interview:

> Mr. H: Stefan, I know that you, one of the things you talked about, was it’s tough with working, you know, getting to the videos and stuff like that?
>
> Stefan: After… outside of school, I have nothing but work to do.

Mr. H: Right, right. So, do you think there's a way for a teacher to, to do it that would be accessible for all students or is it just, that's just kind of the nature of jobs?

Stefan: It's just having a job. It's a lot harder in school.

Stefan worked as a diesel mechanic outside of school, and his job required long, strenuous hours. He was aware of the hours that would also be required to be successful at school. However, for him, the tradeoff was not worth his effort. He would have to take away time from earning money to complete the Algebra 2 requirements. In his opinion, the cost of doing math was not worth his time. Deci and Ryan (1985) and Jiang et al. (2018) indicated that the negative costs can cause people to not even attempt tasks. Baker and Robinson (2017) concur, but specifically point out secondary students not even completing assignments. Alina Hadley echoed Stefan's sentiment during the focus group interview:

> It was hard to like go to work, get off, go home, try to get ready to go to bed, and everything and then, oh crap. I have a video to watch. And then the videos were like 30, 45 minutes to an hour long. It was hard to stay focused, especially after work.

Alina worked at a local restaurant after school, and she pointed out the issue of having lengthy videos to watch when she was ready to go to bed. The time that was required to watch the videos was interfering with her basic human need for sleep. Her obligations outside of school were more important in her eyes. Lan Risto reiterated the length of videos and his lack of desire to watch them when he stated, "I feel that it was giving me a taste college, with the hours of videos to watch, unwillingly." His unwillingness was his statement that the cost of doing the math was not worth his effort. During the focus group interview, Catherin Klyment discussed teachers who expect students to put in extra time. She stated, "Some of us don't have time to come after school." For Catherin, she expected the teacher to work with her during school. She did not have the time after school to meet the cost of doing math.

Although students were reluctant to incur the cost that was required to do the math, they realized that their effort was necessary to succeed and knew that they were an essential part of the process. During the focus group interview, Catherin Klyment said:

> It felt like you put in the extent that you could to motivate us and do what you could on your part to help us with whatever we needed help with. But then we had to meet you that way. Like you were willing to actually go that extra mile. As long as we met you there.

Catherin stated that she knew I was working as hard as I could to help them succeed, but students needed to meet me with equal effort. Alina Hadley concurred during a response to the interview, "Until we want to put the effort in and want to succeed in the class, it doesn't do any good for you to put the effort in, to even try to keep us motivated." Alina recognized the importance of students' effort to be successful. She stated that my efforts at motivation were ineffective, if students did not care to give effort. In the focus group interview Antonia Teagan noted that students even affected their teachers, "It kind of makes the teacher not even want to teach sometimes cause there's kids that don't care anymore." Antonia stated that her teachers observed students' lack of motivation and let it affect their instruction. During the semester, other students also implied their lack of desire to put effort into math. In an early journal response, Sarah Abbey said, "I didn't enjoy thinking about math." Even though Sarah mentioned that she wanted to receive good grades, even thinking about math was not fun for her. When students cannot find enjoyment in an activity, they are less likely to be motivated to start or complete that activity. Satisfaction is a critical component of motivation (Keller, 1987). Because Sarah was not enjoying thinking about math, she was not willing to pay even the cost of thought. Students consistently pointed out their decreased motivation to do math due to the time that was required. They were unwilling to pay the cost. Students also mentioned another time component that was affecting their motivation.

Lack of intrinsic motivation. As I examined my students' responses about their lack of desire to embrace the cost that doing math required, I also began to see a common thread of intrinsic motivation being impeded by the time period of the school year. Students did not only lose motivation due to the time required by general math studies. They also lost motivation due to the impending spring break and summer break, which was a result of my study being completed in the spring semester. In the beginning of the innovation, Aleksandra Murali responded to a journal prompt with:

> This week in math class, I worked as hard as I could because I wanted to give myself time to work on my essay. This week it was important for me to understand the math because I was absent for one day, and didn't want to get behind.

Aleksandra indicated how much effort she was willing to expend early in the innovation phase. She was intent on working hard and understanding the math. At the time, Aleksandra was explaining to me that her motivation was at a high level for problem-based learning and math skills. Early in the semester, Kristiana Jeppe also mentioned in her journal responses how her motivation was increasing and she was enjoying math. In her journal response, Kristiana said, “Towards the beggining [sic] of the semester I felt very unmotivated, but now I am feeling some what [sic] better about math, with more motivation. Just not a lot.” Before the innovation started, Kristiana commented about her lack of motivation. She believed that her motivation had increased once the innovation had started.

However, as the semester progressed, students admitted to having less internal drive as they were approaching spring break. Students who had previously indicated higher motivation, mentioned declining motivation. In another journal response, Aleksandra Murali said, “I feel like my motivation has decreased slightly due to spring break coming up.” The time of year was affecting student motivation to start and complete math. Aleksandra stated her feelings very obviously. Her motivation had decreased slightly from earlier in the semester. During the focus group interview, I explored this category further. Antonia Teagan explained her thoughts in a lengthy reply, and the other participants nodded in agreement:

> There's in each part of like the school year, at the beginning, I'm at my peak. That's where I'm, you know, going at it. Really trying to get my grades in. And then during this time, especially during spring break, I just, I, it takes a little more in me to, you know, push through. At one, cause like summer's coming up, um, I'm just, I'm just ready to get out of school. But that's just me. Like, I feel like that I'm not the only one speaking too. Other people. That just around this time. You just, you're, you're, you're done.

Antonia explained that the time period of the school year affected her motivation. When she mentioned being at her peak, she meant that her motivation to succeed was at a higher level. As the semester progressed, she said that it took more motivation to push through. Then, she highlighted the specific reason for being less motivated. The time of school year fostered an attitude of reaching her limit, which she described as being "done."

To delve further, I specifically asked focus group interview participants if shifting the start of the innovation closer to spring break would increase their motivation during that difficult time of year. My question was whether problem-based learning in a flipped classroom would be a welcome change to traditional instruction later in the semester. Antonia Teagan stated, "I would do it, but it wouldn't be my best work. Like, let's say, I did in the beginning of the year." Antonia reiterated the fact that the time of year would still be affecting her motivation to work in math class. She was explaining that the innovation would not affect her as much as the time of year. Antonia explained further, "Let's say if we did the flipped or the hybrid and we changed to just watching videos at home and then coming to school, I think, I don't know. It's hard to say just because during the time of year, like you're just done." Again, she pointed out the concept of students just being "done" during this time of the school year. Lan Risto agreed, "I know if we had to do it at home and it's this close to spring break, I wouldn't do it." Lan claimed that he would not even complete the work at home close to spring break. Catherin Klyment also said, "I feel like during this time we all, like, kind of, — Oh well, I'll get it back up after spring break. We kind of give up at home." Students' desire to be on a break from school was overpowering students' motivation to start and complete math assignments.

Theme 5: Students developed real-world skills through engaging, relevant, and high value tasks.

Students' responses to journal prompts and responses during the focus group interview suggested that students were participating in problems that were not what they were accustomed to finding in traditional math instruction. Problem-based learning provided students with engaging, relevant, and high value tasks that helped students develop real-world skills. My students and I both observed that the problems were engaging their attention and effort during class time. Students were willing to invest their actions and brain power into solving problems. Fredricks and McColskey (2012) and Ozkal (2019) point out that students are engaged when they choose to participate behaviorally, emotionally, and cognitively. Markušić and Sabljić (2019) also noted a huge difference in student activity when doing problem-based learning. Problems were relevant to students' lives outside of school and topics that they enjoyed. As Keller (1987) encourages, students were given problems that connected with their current lives or futures. Real-world problems can be a motivating factor that makes class more interesting for students (Le Roux, 2008). My students and I also noticed that tasks were valuable to their current class and future. Specifically, students were obtaining skills that should transfer to real-world scenarios. This value for their lives motivates students to participate in class (Matthews, 2017). Theme Five was established by three supporting categories: (a) engagement, (b) relevance, and (c) task-value.

Engagement. At the beginning of the semester, I gave students a survey to gain some information about them and their experiences in math classes. One question asked if students were engaged in their math classes. Fredricks and McColskey (2012) identified engagement as an outward display of motivation through participation behaviorally, emotionally, and cognitively. I noted students' responses in my research journal: "Nine said they were actively engaged, 10 said they were somewhat engaged, two said they were not engaged, and one did not answer" (January 7, 2022). A majority of the students claimed to be engaged in their math classes. However, my students also admitted to me that they did not complete any work at home during the COVID lockdowns. At the beginning of our semester, we also had digital learning days due to snow. Only seven out of my 22 students completed any work at home. Due to the nature of problem-based learning in a flipped classroom, student participation was a point of concern. After my innovation was completed, I analyzed students' responses to journals and the focus group interview for engagement behaviorally, emotionally, and cognitively.

Early in the innovation, students remarked about their emotional engagement with the new style of math class. In a journal response, Yasmin Nabuko said, "Math was interesting for me this week because I never have worked on a project in math." Yasmin believed that we were doing something different, and it made math class more interesting. Yasmin meant that she was more willing to see what math class had to offer than usual. Bertrand Androkles also stated in a journal response later, "Math class was fun because of the interaction aspect of the school app we created as a group and also the criticism part." Bertrand enjoyed working with others, and it made math class more fun. Another student, Kristiana Jeppe, echoed Bertrand's sentiment, "Math class was fun this week, because we got to work in groups and design an app." Kristiana was also engaged emotionally with the activity of creating a student app for a phone. I even noted in my observation journal:

> I think that their familiarity with cell phones and apps made this project more exciting and attention grabbing. The term "digital native" is abused at times, but their experience with phones and love of phones did make them more engaged with the topic (March 4, 2022).

I also noticed their emotional engagement with the topic of our Student App PBL. Students were interested in actually participating in something that connected with their life.

Students also displayed motivation through their behavioral engagement. Students actively participated in problem-based learning experiences. Often, getting students to participate has been an issue in my Algebra classes. In a journal response, Loren Paul observed, "Math class was more enjoyable this week because we incorporated more group work, but not only that, it seemed as though the whole class talked to each other while presenting our business plans as we gave and received feedback on our work." What Loren witnessed was her fellow classmates and herself participating actively in math class. The Business Plan PBL was the very first experience that students had with problem-based learning. Students, like Loren, were already commenting on their motivation to actually participate more in math class and cooperatively. Later in the innovation phase, I decided to introduce the problem-based learning experiences without the promise of a grade. It was a way for me to judge if students were motivated to problem-solve without an extrinsic motivator. In my observation journal about my second attempt at this technique, I noted, "Again, students jumped directly into problem solving. They began questioning: 'Can I do this….?'" (March 31, 2022). Instead of students waiting on me as the teacher to extrinsically motivate them, they immediately jumped in to solve the problem of turning $10,000 into $100,000. They were excited to try different ideas and were curious about what I thought of their ideas. Their excitement displayed an instant behavioral engagement, but also emotional and cognitive engagement.

Finally, students also displayed motivation to cognitively engage with math and our problem experiences. In my classroom, students arguing about answers or discussing the topic of class is usually a sign that they are engaging with a topic cognitively. During the Business Plan PBL, I remarked in my observation journal, “There were disagreements and argumentation for support. It was fun to see the students defending their business. It was definitely a lively class. It felt like the students were learning more than just the math skills” (February 15, 2022). I witnessed my students thinking about a topic deeper than they normally would. They had to respond to questions and argue their position without my assistance. They could not rely on repeating given steps for a math problem. During the Global Warming PBL, Marie Raju responded in her journal, “This week in math class, I worked as hard as I could because I wanted to research as much data for my global warming essay.” Marie was describing her engagement with the topic cognitively by explaining how hard she worked and actually doing research on the topic at hand. The experience of interacting with these problem-based learning topics that were not directly about Algebra 2 produced more cognitive engagement with the Algebra 2 topics that we covered as well. In one class, I observed in my journal that “They also seem more willing to ask me questions. They are seeking more understanding compared to previously just seeking answers. They are asking ‘how?’ instead of ‘what?’ The process of math is more important” (March 7, 2022). I noticed that my students were not just passively absorbing information but wanted to understand topics at a deeper level. Instead of seeking for the answer, they were asking about the process of problem-solving.

Relevance. During the problem-based learning process, students participated in tasks that were relevant to their lives currently or in the future. Keller (1987) encouraged design of instruction that contains relevance for students. Dimitroff et al. (2018) noted that their students felt more motivated by classroom topics connected to their lives, hobbies, or future careers. In their journal responses and verbally to me in class, my students mentioned on a variety of occasions that they perceived the topics were relevant to them. Some even stated that topics were foreign to them, but they realized that it could affect them, as in the case of our Global Warming PBL. In the focus group interview, Miriam Fatema said, “Honestly, I don't [sic] even know what climate change was until that project. So, it honestly like opened my eyes a lot.” Some students, like Miriam, were finding relevance in math class for the first time. Even with climate change presented throughout the news, Miriam was still just beginning to learn its relevance for her life. Her experience could make her better prepared to be a part of the solution in her future.

During our first problem-based learning experience, I reported a comment that was spoken aloud during our presentations of our Business Plan PBL, “Alina Hadley stated that it made her understand more about why we were learning systems of equations that involved satisfying multiple variables.” Alina realized that creating a business required the owner to satisfy multiple variables at the same time, while staying within constraints of the real-world. She made a connection with the Systems of Equations unit that we were currently studying in our flipped lessons. Not only did Alina make a connection to the real world, she also realized the relevancy of Systems of Equations. At the end of the innovation phase, Alina stated in the focus group interview, “But, you really, like, showed us that, like, it actually applies to the real world, not in just like small little areas, but like overall big, big things that we have to worry about.” Alina believed that she was learning lessons that applied to large topics in the real-world. The open-ended nature of problem-based learning allowed Alina to explore many aspects of the real-world topics in our problem-based learning experiences. She noticed that problems were not too highly specific to one small concept.

Furthermore, students pointed out their observation that the problem-based learning experiences would help them in their future lives. For the first journal response during the innovation, Kristiana Jeppe said, “Last week and this week it was important for me to understand the math, because we were learning about real world experiences that could help in the future.” Kristiana made the connection that the Business Plan PBL and Student App PBL could benefit her in tasks that she may complete in the future. Kristiana was a natural leader in her class, and can be very successful in the future. To her, these real-world experiences were going to help her succeed. She was indicating that the relevance would come later in life. During the focus group interview, Lan Risto agreed:

> Uh, I think that this class especially like helped me prepare for like, what's coming on, like a future. So, like with jobs, college, stuff like that, our... The math I learned in this class, I could apply it to real life stuff. Because, I used to always be like, I'm never gonna’ use this in my life. Like, I’m never going to use this certain math and then we did problem-based learning. I'm like, oh, I'm really going to use this in life.

Lan perceived that mathematics was going to be useful for his life. He stated that he had second thoughts about math due to problem-based learning. He experienced problems that were relevant. Loren Paul explained her thoughts in a journal response. She said, "This year's Algebra 2 course was very different from your traditional high school math class. We spent a great deal of time applying what we learned to scenarios that will come about in our futures." Loren also noted the difference between this year and a traditional math class. She was aware that we had learned about relevant situations that would affect her future.

Task-value. Jiang et al. (2018) defined task-value as tasks that students see as interesting, personally important, and useful. My students and I observed that problem-based learning was introducing tasks that had multiple benefits beyond our classroom. Real-world skills through fun tasks provided students with value in class. In a journal response, Aleksandra Murali said, "I learnt [sic] that when it comes down to real life things are more complicated than you think. Additionally, that there are more steps and things that you have to think about when it comes to solving a problem." This journal response was early during the innovation phase. Aleksandra was already seeing the value of the tasks like the Business Plan PBL. She thought that problems in life were simpler, but realized that there are numerous things to think about when solving a problem in life. By her response, Aleksandra implied the value that these tasks had brought to her life. During the Student App PBL, I noted in my observation journal, "Creativity is starting to blossom a little more in student work. The freedom of expression seems to be fostering creative skills" (March 3, 2022). For the Business Plan PBL, students had selected common businesses, such as restaurants, travel agencies, and bridal shops. They also used very simple Google Slides for presentations. However, I noticed that the problem-based learning was beginning to elicit more creativity on the second PBL. Students were creating unique names for their Student Apps and even designing logos. The tasks were valuable for improving students' work.

Additionally, my students and I noted a major component of problem-based learning being the utility of problem-solving outside of the math classroom. During the focus group interview, Antonia Teagan discussed problem-based learning, "So like, that also helped me see that, you know, Algebra is used in the real world. So, that also helped me see that math isn't just in your classroom." Antonia proclaimed that problem-based learning helped her see that Algebra could be used in the real-world. Antonia's tone of voice also indicated her thankfulness. Antonia emphasized the word 'is' with great inflection in her voice, when she described that I helped her see Algebra is used in the real-world. Students in my class often struggle with why they should learn Algebra. According to Antonia, problem-based learning was providing a valuable answer to that question. She did not hesitate and construct her answer, so she had already contemplated how problem-based learning had created an experience for her that truly helped her see the real-world in Algebra. Antonia also expounded further: "I would say I know more than someone that wouldn't have done that, another Algebra 2 class. Just by the friends I talked to and stuff like that." Antonia was also able to see the value of tasks in our course, by comparing to her peers in other Algebra classes. She was pleased that different instructional design had provided her with a different Algebra 2 experience.

For the Global Warming PBL, students were required to complete an essay on reducing global warming while increasing industrialization in underdeveloped countries. On the day that their essay was due, I observed the following in my observation journal:

> We had an open discussion on things that cause global warming, how to combat against (reduce) global warming, and what industrialization means in that context. Over half of the class mentioned issues with fossil fuels. So, I asked, "Would electric vehicles solve the issue? How are the batteries created? What about the plants for making electric vehicles?" I wanted them to be able to question both sides of the argument. This would give them the ability to leave my class and possibly be leaders in a better solution. Students mentioned that they had not thought about the manufacturing process of electric vehicles contributing to global warming (March 18, 2022).

I noted several valuable components of problem-based learning through this observation. Students were able to participate in a discussion in math class. Typically, traditional instruction does not employ a technique like discussion (Magliaro et al., 2005; Schunk, 2016). Problem-based learning also allowed me to guide students with questioning, instead of just rote memory of steps. Due to this questioning, students discovered new knowledge to frame their arguments. Finally, students gained the valuable experience of the research process. I was encouraged that my students received better preparation to become problem solvers in the future. The value of future utility is what I reiterated with my observation. The problem-based learning experience provided high-value tasks for my students.

Chapter Summary

Throughout this chapter, I have discussed the analysis of my data sources and the resulting findings. The purpose of this action research was to examine the impact of problem-based learning in a flipped classroom instructional environment on motivation and achievement in math. Quantitative data was collected from a diagnostic test and a motivation survey. To measure achievement, I utilized a Diagnostic Test on Systems of Equations and Quadratic Functions. Findings from the Diagnostic Test indicated a significant increase from preinnovation to postinnovation measures. Students' posttest mean scores were significantly higher than the pretest mean scores, $t(21) = 4.75$, $p < .001$, Cohen's $d = 1.01$. To measure student motivation, I utilized a Motivation in Mathematics Survey. Students' responses were not significantly different in overall motivation or self-efficacy subscale scores from preinnovation to postinnovation measures. The paired samples t-tests did not return a significant p-value for overall motivation or any subscale.

Qualitative data was collected through observation notes, student journals, and a focus group interview. I utilized several rounds of coding to record salient thoughts. A variety of a priori codes were used, as well as emergent codes from multiple cycles of reading and interpreting the data. Codes were grouped into emergent categories, and categories were later grouped into overarching themes. Five major themes were established: 1) Students desired more traditional structure than problem-based learning in a flipped classroom.; 2) Problem-based learning was time consuming and prevented practicing math skills.; 3) The encouragement and effort of their teacher positively affected their motivation more than other factors.; 4) Motivation was lower due to time required and time of the school year.; and 5) Students developed real-world skills through engaging, relevant, and high value tasks. Discussion about the results and themes will follow in the next chapter with implications and limitations.

CHAPTER 5

DISCUSSION, IMPLICATIONS, AND LIMITATIONS

This section is intended to situate the findings from quantitative and qualitative data sources within the literature about motivation, problem-based learning, and flipped classrooms. The purpose of this action research was examining problem-based learning in a flipped classroom instructional environment and measuring its effect on students' motivation and achievement in Algebra 2 at Pali High School. Quantitative findings from the Diagnostic Test on Systems of Equations and Quadratic Functions indicated that students' scores significantly increased ($t(21) = 4.75$, $p < .001$, Cohen's $d = 1.01$) from preinnovation to postinnovation measures. However, students' responses on the Motivation in Mathematics Survey did not significantly differ in overall motivation ($t(21) = .91$, $p = .187$) or self-efficacy ($t(21) = 1.69$, $p = .053$) subscale scores. Qualitative findings from observation notes, student journals, and a focus group interview were analyzed to establish five themes: 1) Students desired more traditional structure than problem-based learning in a flipped classroom.; 2) Problem-based learning was time consuming and prevented practicing math skills.; 3) The encouragement and effort of their teacher positively affected their motivation more than other factors.; 4) Motivation was lower due to time required and time of the school year.; and 5) Students developed real-world skills through engaging, relevant, and high value tasks. The following sections cover (a) discussion, (b) implications, and (c) limitations of this action research.

Discussion

Throughout this research, there were four research questions guiding my inquiry: 1) What is the impact of problem-based learning in a flipped classroom instructional environment on students' motivation in mathematics?; 2) What is the impact of problem-based learning in a flipped classroom instructional environment on students' self-efficacy in mathematics?; 3) What is the impact of problem-based learning in a flipped classroom instructional environment on students' mathematics achievement on Systems of Equations and Quadratic Functions?; and 4) What are students' perceptions of problem-based learning in a flipped classroom instructional environment? Each of the research questions will be discussed below. Research and findings from this study will be integrated to expound upon the outlined research questions.

Research Question 1: What is the impact of problem-based learning in a flipped classroom instructional environment on students' motivation in mathematics?

For this study, motivation was defined as an intrinsic or extrinsic force that initiates, guides, and sustains activities or behaviors aimed at achieving a goal (Deci & Ryan, 1985; Dimitroff et al., 2018; Hornstra et al., 2018; Yurt, 2015). Dimitroff et al. (2018) allude to the fact that motivation has been a metaphysical concept explaining why individuals take certain actions. Defining motivation, however, and what we attribute it to, can be a point of contention (Dimitroff et al., 2018; Keller, 1987; Yurt, 2015). Motivation can have internal loci of control, as well as external influences (Hornstra et al., 2018). Motivation is the driving force behind what individuals choose to do and what makes them sustain their effort (Dimitroff et al., 2018; Thaer & Thaer, 2016).

In this study, the overarching goal of the first research question was to ascertain if changing instructional design would have an impact on motivation in math. In addition to the measurement of impact, the qualitative data gave reasoning for students' motivation, or lack thereof, in two major categories also expressed in the literature. Students' motivation was either encouraged or inhibited. Researchers utilized a variety of different words to represent these two categories. Below, I discuss the (a) impact of problem-based learning and flipped classrooms on motivation throughout the research, (b) barriers to motivation, and (c) enablers of motivation.

Impact on motivation. Teachers' are responsible for creating classroom environments that have elements from the conceptual framework of the ARCS Model to support motivation (Baker & Robinson, 2017). Implementing problem-based learning in a flipped classroom was the instructional design change for this study. Meredith (2015) stated that "faculty members and students considered problem-based learning as a tool to improve student motivation, critical thinking, and overall learning" (p. 47). Baker and Robinson (2017) and Fukuzawa et al. (2017) saw a significant difference in motivation through the use of problem-based learning versus direct instruction. When interviewed about problem-based learning, teachers stated that students displayed more motivation, self-confidence, responsibility, and problem-solving skills during problem-based learning (Ghufron & Ermawati, 2018). Teachers responded to a survey that they noticed a huge difference in student activity when doing problem-based learning versus direct instruction, and that students were not as motivated or interested during direct instruction (Markušić & Sabljić, 2019).

The flipped classroom inserted a technology aspect to this study as well. Technology integration for each student led to increases in motivation, according to a meta-analysis by Harper and Milman (2016). Zheng et al. (2016) also noted that one-to-one laptop studies reported increased motivation, engagement, and persistence. Some researchers also noted students' engagement during flipped instruction. Fredricks and McColskey (2012) identified engagement as the outward display of motivation. Amstelveen (2019) observed that students were more engaged during flipped instruction versus traditional instruction. In a flipped classroom, Gaughan (2014) stated that her students were more engaged with course material which is a signifier that they were motivated to learn.

In this study, motivation was measured before and after the implementation of problem-based learning in a flipped classroom. Although previous research suggested that motivation would be positively affected, students' responses were not significantly different between preinnovation (M = 4.36) and postinnovation (M = 4.45) overall motivation scores. Students displayed signs of motivation throughout the innovation period. Students claimed to be interested in math class and were highly engaged with problem-based learning activities. My students and I both observed that the problems were engaging their attention and effort during class time. Students were willing to invest their actions and minds into solving problems. Nevertheless, students' overall motivation scores on the survey indicated there was not a significant change in their motivation. This discrepancy in scores could be due to several different influences presented in my qualitative analysis. The novelty effect of instructional design change did not last, as students specified a desire to have more traditional structure for lessons.

Students explained that problem-based learning interfered with time that would have been available to practice math skills in a flipped classroom. As a result, students' confidence in math declined.

Different researchers have utilized different wording to describe intrinsic and extrinsic forces that affected motivation. Sample wording from researchers are the following: intrinsic and extrinsic *drives* (Nenthien & Loima, 2016), *support* for student motivation (Keller, 1987), *factors* that guide individuals' actions (Yurt, 2015), and *reinforcers* (Driscoll, 2005; Keller, 1987; Schunk, 2016). For this study, barriers to motivation and enablers of motivation were selected to convey the particular way they affected students' motivation. In the following sections, barriers and enablers from problem-based learning in a flipped classroom are discussed.

Barriers to motivation. Yu and Singh (2018) pointed out that students who preferred one type of instruction over another did not necessarily become more motivated. At the beginning of this study, students were excited to experience activities different from traditional math classes. The break from traditional direct instruction engaged my students behaviorally, emotionally, and cognitively, which Fredricks and McColskey (2012) and Ozkal (2019) denoted as outward displays of motivation. For my students, engagement with problem-based learning experiences remained strong throughout the study. However, they indicated a desire to return to traditional in-person instruction versus the flipped classroom. The observation of this desire led to one of my themes from qualitative analysis that problem-based learning was time consuming and prevented practicing math skills.

The lack of practice on specific course material was noted by research as well. Fukuzawa et al. (2017) noted that some students felt they were not actually learning the course material during problem-based learning. Students noticed the benefit of the learning process and collaboration, but they still desired presentations on subject matter (Fukuzawa et al., 2017). Lack of practice on content can result in reduced confidence, and thus, lower levels of motivation to succeed (Keller, 1987). In this study, my students also lamented that they were not understanding the math as well as they would like. Students actually asked for more practice worksheets in class. The flipped classroom provided time in class for problem-based learning experiences. Students watched flipped lesson videos at home and applied math skills at the beginning of each class. However, my students believed similarly to previous research that there was not enough time on math skills. As a result, my students began to think that problem-based learning was interfering with their development of math skills. This interference led to lack of confidence, which is essential support for motivation (Keller, 1987). For my students, confidence meant their ability or effort being enough to affect achievement on math skills. They expressed their "lack of confidence" and "not understand[ing] the math." As the innovation phase progressed, another barrier to motivation became more predominant.

Jiang et al. (2018) connected motivation to expectancy-value-cost constructs, specifically defining the cost construct as negative consequences associated with completing tasks. Cost can have intrinsic and extrinsic dimensions. Students can feel the effort level required is too high, or external rewards do not match the effort required (Jiang et al., 2018). In this study, students explained that the cost of time spent at home was too much for them to sustain their motivation. They claimed that flipped lesson videos were taking too much time outside of school. For my students, time outside of school compounded with limited time in class due to problem-based learning. Students did not watch the videos completely and had less time in class to practice skills. The cost of math caused their motivation to decline, and their declining self-efficacy in math skills caused motivation to decline further. Students also pointed out that the time of school year was a major barrier to their motivation, with impending Spring and Summer breaks approaching. As a result, my students' responses on the cost subscale decreased in mean score from preinnovation ($M = 4.52$) to postinnovation ($M = 4.35$). Even though students had negative impacts to their motivation, they were open about influences that enabled their motivation as well.

Enablers of motivation. Keller (1987) specifically advised educators to design instruction that accessed as many categories of the ARCS model as possible: attention, relevance, confidence, and satisfaction. Hornstra et al. (2018) suggested exciting learning, interest in the topics, and pleasurable experiences as enablers of motivation. The real-world problems of problem-based learning utilized in this study were intended to enable motivation due to higher student interest. Problems intertwined the attention and relevance categories of the ARCS model. Le Roux (2008) has called real-world problems motivating factors. Students have been more motivated when classroom topics were relevant to their lives, hobbies, or future careers (Dimitroff et al., 2018).

In this study, problem-based learning was specifically designed to address the ARCS model. Throughout the innovation phase, students were interested and attentive to the topics of the various PBL experiences. Students were very vocal about the relevance that the topics held for their lives. Many students expressed how they finally understood the need for math in the real-world. Early in the innovation phase, this feeling translated into more motivation to work hard on course topics. However, the cost of time and period of school year eventually outweighed this motivation.

Research Question 2: What is the impact of problem-based learning in a flipped classroom instructional environment on students' self-efficacy in mathematics?

For this study, self-efficacy was defined as an internal belief that one can succeed at a task (Deci & Ryan, 1985; Jiang et al., 2018). In previous research, students who were confident in their ability to accomplish math tasks were more likely to be motivated to engage in high level thinking and increase their achievement (Hwang, 2016). Jiang et al. (2018) defined self-efficacy as students' competence beliefs in their abilities. Hwang (2016) identified self-efficacy as a motivational construct closely related to the confidence category from the ARCS model. Both researchers indicated that self-efficacy was a strong predictor of motivation to engage and achievement (Hwang, 2016; Jiang et al., 2018). Fear of failing can cause a lack in confidence and low self-efficacy (Keller, 1987).

In this study, the overarching goal of the second research question was to determine if changing instructional design would have an impact on self-efficacy in math. Below, I discuss research and my findings on the (a) impact of problem-based learning and flipped classrooms on self-efficacy and (b) influences on self-efficacy.

Impact on self-efficacy. In a flipped classroom experience, Amstelveen (2019) indicated that students were able to increase interactions with each other and receive more prompt feedback on their skill development. In this study, feedback was immediate on practice problems during class. Research has reported that prompt feedback from teachers can lead to higher student confidence with content (Skinner et al., 2008). Higher levels of confidence can lead to increased achievement (Hwang, 2016; Jiang et al., 2018). During problem-based learning, teachers have stated that students displayed more motivation and self-confidence (Ghufron & Ermawati, 2018). Yu and Singh (2018) noted that different styles of instruction did not result in significant effects on two motivational constructs of self-efficacy and interest in mathematics.

In this study, the self-efficacy subscale was measured before and after the implementation of problem-based learning in a flipped classroom. Although some research suggested that self-efficacy would be affected, Yu and Singh (2018) noted that different styles of instruction did not display significant effects on self-efficacy. In this study, findings related to my students were consistent with Yu and Singh (2018). There was not a significant difference between students' preinnovation ($M = 4.25$) and postinnovation ($M = 4.54$) self-efficacy scores.

Influences on self-efficacy. Jiang et al. (2018) defined self-efficacy as students' competence beliefs in their abilities. Hwang (2016) identified self-efficacy as a motivational construct closely related to the confidence category from the ARCS model. Researchers have reported that student confidence can be affected by students' personal motivational beliefs, prior academic achievement, and personal academic goals (Patrick et al., 2007). However, confidence that is reinforced by teacher support can lead to students who are more likely to be motivated to engage in current and future tasks (Skinner et al., 2008). Increased teacher support can be offered in a flipped classroom to build student confidence and knowledge in mathematics, which would support higher motivation through students' self-efficacy (Keller, 1987; Nenthien & Loima, 2016). Gaughan (2014) indicated students perceived increased knowledge with a topic after watching a flipped video before practice in class.

While the self-efficacy measure showed a small increase in my students' self-efficacy, the qualitative findings differed and suggested that the perception of self-efficacy in math may have actually decreased during the innovation. As mentioned in the previous discussion on overall motivation, my students observed that problem-based learning interfered with practicing math skills during class. Due to this interference, they lost belief in their math competence. Students were not confident in their ability to do well on math skills. For example, Stefan Hari stated, "I do not understand the math," which pointed to an internal belief that he did not understand math and did not believe he could succeed. While Stefan did not mention self-efficacy directly, he spoke of his lack of belief that he had the ability to do math broadly. This belief of Stefan's and expressed by other students agreed with Jiang et al.'s (2018) definition of self-efficacy: Cost, or perceived negative consequences of engaging in a task (Jiang et al., 2018), was ascribed to problem-based learning with a result of poorer math knowledge and skills. Students attributed their inadequate math skills to the problem-based learning experience stealing time from practice on math skills. Students' statements above and my findings led to the conclusion that time on problem-based learning detracted from direct math content and skills. Therefore, lack of time to practice negatively impacted students' confidence and self-efficacy in math.

Research Question 3: What is the impact of problem-based learning in a flipped classroom instructional environment on students' mathematics achievement on Systems of Equations and Quadratic Functions?

For this study, achievement was strictly measured on an objective performance assessment covering Systems of Equations and Quadratic Functions. Because it was specific to performance, it was not a measurement of overall learning. According to Alexander et al. (2009), "Learning is a multidimensional process that results in a relatively enduring change in a person or persons, and consequently how that person or persons will perceive the world and reciprocally respond to its affordances physically, psychologically, and socially" (p. 186). Learning is long lasting. It is a permanent change in how students interact with their surroundings, not just recall of information (Alexander et al., 2009). Performance, instead, is recalling information or remembering how to do tasks. Performance measurements are only one indicator of achievement, as good performance can occur without actual learning taking place (Soderstrom & Bjork, 2015). In this study, students displayed their abilities to solve math problems but applying their abilities in different situations was very different. Measuring long lasting learning was not within the scope of this study. However, Soderstrom and Bjork (2015) indicated performance as what we can observe and measure during instruction.

In this study, the primary goal of the third research question was to ascertain if changing instructional design would have an impact on students' achievement in Systems of Equations and Quadratic Functions. Below, I discuss the impact of problem-based learning and flipped classrooms on achievement.

Impact of problem-based learning and flipped classrooms on achievement. Meredith (2015) stated that "faculty members and students considered problem-based learning as a tool to improve student motivation, critical thinking, and overall learning" (p. 47). Teachers noted the successfulness of learning outcomes and observed improvements in critical thinking and creativity under problem-based learning (Markušić & Sabljić, 2019). Iswandari, Prayogo, and Cahyono (2017) and Lin (2015) observed significant increases in vocabulary after implementing problem-based learning. However, Fukuzawa et al. (2017) noted that some students expressed they were not actually learning the course material; students noticed the benefit of the learning process and collaboration, but they still desired presentations on subject matter.

Similarly, Amstelveen (2019) noted that the flipped classroom promoted more engagement from students, which can lead to higher levels of achievement according to Lei et al. (2018) and Ozkal (2019). Gaughan (2014) reported students were glad to know learning content background before in-class portions of the lesson, and students were more in tune with their teachers' thinking. In a meta-analysis by Zheng et al. (2016), benefits of technology-enhanced lessons included an increase in academic achievement. Some students believed they learned better through flipped video lessons (Amstelveen, 2019). Moreover, a recent study by Ramadhani, Umam, Abdurrahman, and Syazali (2019) employed a flipped classroom with problem-based learning and found significant improvement in students' mathematics knowledge.

Findings from this study agreed with previous research that problem-based learning and flipped classrooms can significantly affect achievement (Amstelveen, 2019; Gaughan, 2014; Iswandari et al., 2017; Lin, 2015; Ramadhani et al., 2019). In this study, postinnovation achievement on the Diagnostic Test on Systems of Equations and Quadratic Functions did result in a significant increase in student learning (Preinnovation *M* = 32.68; Postinnovation *M* = 51.38). However, the mean postinnovation score of 51.38 still fell below state and school district expectations for college and career readiness.

This result was not surprising after I considered my students' indication that their intrinsic motivation was lower due to cost of time and period of school year. The cost subscale mean score of the Motivation in Mathematics survey decreased from preinnovation (*M* = 4.52) to postinnovation (*M* = 4.35). Other research has suggested lack of motivation and achievement were negatively correlated. For example, Abu-Hamour and Al-Hmouz (2013) found the highest correlation between intrinsic motivation and achievement in a math classroom. Lower levels of motivation, whether intrinsic or extrinsic, have correlated to lower academic achievement (Nenthien & Loima, 2016). Kiefer et al. (2015) noted that motivation drives and sustains behavior leading to school success. Teachers attributed scores on performance tests and overall achievement to a lack of motivation in mathematics (Amstelveen, 2019).

Research Question 4: What are students' perceptions of problem-based learning in a flipped classroom instructional environment?

Students' perceptions were defined as the lived experiences of my students during the innovation. Transitioning to more student-centered and active learning designs creates different classroom experiences for students (Tendhar et al., 2019). When interviewed about problem-based learning, teachers and students both agreed that there was more motivation, self-confidence, responsibility, and problem-solving skills during problem-based learning (Ghufron & Ermawati, 2018). Even though Meredith (2015) stated that problem-based learning was viewed as assistance to overall learning, Fukuzawa et al. (2017) noted that some students felt they were not actually learning the course material. Eppard and Rochdi (2017) claimed that most students had an overall positive experience with flipped learning. Some students believed that they learned better through flipped video lessons (Amstelveen, 2019). Students during action research by Gaughan (2014) commented that they were glad to know lesson background before in-class activities. Problem-based learning in a flipped classroom was an instructional design capable of changing perceptions.

In this study, the aim of research question four was to gain richer descriptions of students' experiences with problem-based learning in a flipped classroom. Four key categories of findings emerged through analysis. Below, I discuss (a) traditional structure for math skill development, (b) time consumption, (c) engaging, relevant, and high-value tasks, (d) teacher support as motivation.

Traditional structure for math skill development. Traditional math instruction has divided mathematical concepts into more manageable parts for students (Magliaro et al., 2005). It has allowed practice and timely feedback with skills before higher level problems (Magliaro et al., 2005). Problem-based learning in mathematics has been a radical shift away from traditional lecture or direct instruction (Markušić & Sabljić, 2019). Shifts from traditional instruction may provide an initial novelty effect, but some research reports student interest has dissipated over time (Meredith, 2015). Fukuzawa et al. (2017) noted that some students felt they were not actually learning course material. Moreover, students noticed the benefit of the learning process and collaboration, but they still desired presentations on subject matter (Fukuzawa et al., 2017). Teachers also noted lack of class time available to use problem-based learning and still cover subject standards (Markušić & Sabljić, 2019).

In this study, the shift from traditional math instruction challenged my students to leave their comfort zones. The innovation began with excitement about a new style of learning. Problem-based learning provided students with opportunities to participate in engaging, relevant, and high-value tasks. Students indicated their excitement with learning math that "actually applies to the real world." They also understood "why we were learning systems of equations." However, students asserted their desire for more traditional instruction to improve their math skills. They realized the important math skill transfer they were learning, but they were still concerned about doing well with Systems of Equations and Quadratic Functions. During direct instruction, students do receive more time for skill practice and feedback (Magliaro et al., 2005). The flipped classroom during this study was also implemented to provide those opportunities for practice and feedback alongside problem-based learning. However, students expressed that problem-based learning was consuming the time that they needed to "practice math" skills. Students were aware of the value that problem-based learning provided, but still desired to improve their skills on Systems of Equations and Quadratic Functions.

Yurt (2015) suggested that beliefs related to student expectations were the most effective variable on math performance. In this study, students' lack of self-efficacy and confidence led to a decrease in motivation. Motivation and achievement can have a reciprocal relationship, as lower achievement can lead to lower motivation (Hornstra et al., 2018; Mkhize, 2017). The cycle can spiral in a negative direction as well. Thus, my students indicated their desire to have more traditional structure for math skills instruction. Merrill (2002) thought students would learn content as they formulate solutions to ill-structured problems. However, my students disagreed. They were concerned about specific Algebra 2 concepts they missed due to time spent on problem-based learning.

Time consumption. Because problem-based learning involved a less structured and longer tutorial process (Barrows & Tamblyn, 1980; Hmelo-Silver, 2004), there was not as much time for direct instruction on math concepts. PBL was very difficult to implement, because teachers often need more time and good management skills to execute PBL effectively (Ghufron & Ermawati, 2018). Teachers have noted the lack of class time available to use problem-based learning and still address disciplinary content standards (Markušić & Sabljić, 2019). Hmelo-Silver (2012) stated that some studies have also given teachers freedom to offer lectures or direct instruction alongside problem-based learning. The flipped classroom instructional method was applied to combat this issue and provide more opportunity for instructor feedback and enrichment activities (Amstelveen, 2019).

In this study, combining problem-based learning with flipped lessons meant students spent less time overall with Algebra 2 content, processes, and skills. Students disliked the effect that extra time consumption had on practicing math skills. Students stated that problem-based learning was preventing their skills development, and they specifically asked for more practice. Differentiated learning and additional teacher support are benefits of the flipped classroom (Eppard & Rochdi, 2017) that were potentially hindered in my study due to additional time spent on problem-based learning.

Gaughan (2014) experienced issues in her action research with knowing whether a student had watched her flipped lesson videos at home. Additionally, very few teachers maintained a flipped classroom on a permanent basis in the study by Meredith (2015). My students indicated that the tradeoff of time spent watching videos did not reward them with sufficient development of math skills. Although problem-based learning was engaging and valued, students were overwhelmed by the amount of time that was required of them. Moreover, the time needed to view flipped classroom videos were not fully valued by students because the videos did not provide enough skills practice.

Engaging, relevant, and high-value tasks. Ghufron and Ermawati (2018) indicated that problem-based learning increased students' motivation and self-confidence, with some even claiming to love learning. Ghosh (2017) pointed out some students found beauty in mathematics when lessons were presented with methods different from direct instruction. Markušić and Sabljić (2019) found students to be more engaged in problem-based learning versus traditional instruction. Amstelveen (2019) also noted that flipped classrooms provided students more opportunity to engage with material and each other versus sitting quietly and taking notes in a traditional classroom. Corso et al. (2013) showed that the real-world connection allowed students to see the relevance of mathematics to their lives, and relevance motivates students to learn (Keller, 1987). In contrast to the rigidity of traditional instruction, problem-based learning allowed students to encounter real-world problem-solving skills (Ghufron & Ermawati, 2018; Le Roux, 2008; Markušić & Sabljić, 2019; Savery, 2006). Because problem-based learning mimics the messiness of real-world problem solving, it provides opportunity for students to construct meaning outside of the context of normal classroom instruction. Problem-based learning moved problem-solving into real-world examples that are ill-structured and had high task-value for students (Barrows & Tamblyn, 1980; Hmelo-Silver, 2004, 2013). Applications in the form of word problems are typically contrived uses of processes in comparison to actually solving ill-structured real-world examples (Matthews, 2017). Problem-based learning provided students with conveyable problem-solving skills that work in a variety of disciplines and situations (Fukuzawa et al., 2017). Chua et al. (2016) stated that students learned skills that will have lifelong impacts on their approach to problems.

In this study, students agreed with research that problem-based learning introduced them to tasks that were enjoyable and relevant to their lives. Students' enjoyment suggested that they were satisfied with activities or tasks. Satisfaction leads to more motivation in math classrooms (Jiang et al., 2018; Keller, 1987). In contrast to previous research, students' responses on the motivation survey did not show significant increases in motivation, even though students claimed to be enjoying problem-based learning. Skinner et al. (2008) observed that "when children have lost their emotional enjoyment and interest in learning, they are not able to sustain behavioral participation in academic activities over time" (p. 777). In this study, students' responses to journal prompts and responses during the focus group interview suggested that students were participating in problems that were not what they were accustomed to experiencing in traditional math instruction. Their responses to journals indicated that previous research about the value of problem-based learning was correct. Problem-based learning provided students with engaging, relevant, and high value tasks that helped students develop real-world skills. My students and I both observed that the problems were engaging their attention and effort during class time. Students willingly invested their actions and brain power into solving problems. Similarly to my study, Markušić and Sabljić (2019) also noted a huge difference in student activity when doing problem-based learning. Problems were relevant to students' lives outside of school and topics that they enjoyed. As Keller (1987) encourages, students were given problems that connected with their current lives or futures. Real-world problems can be a motivating factor that makes class more interesting for students (Le Roux, 2008). My students and I also noticed that tasks were valuable to their current class and future. Specifically, my students obtained skills that transferred to real-world scenarios. In agreement with Matthews (2017), value for their lives motivated students to participate in class. My students finally understood "why we were learning systems of equations", and how math "actually applies to the real-world." Problem-based learning in a flipped classroom provided my students with a unique experience in Algebra 2 that involved engaging, relevant, and high-value tasks.

Teacher support as motivation. Teachers' praise instills internal beliefs that students are competent enough to complete tasks (Hornstra et al., 2018). Students who expect to be successful persevere even when content becomes more challenging (Keller, 1987; Yurt, 2015). Encouraging and supportive teachers were extrinsic motivators for students (Nenthien & Loima, 2016; Yurt, 2015). Kiefer et al. (2015) studied teacher support and found student motivation increases and more engagement in learning. Classroom climates can have effects on student motivation (Branom, 2013). Nenthien and Loima (2016) emphasized the need for math teachers to increase motivational support for their students. Patrick et al. (2007) further bolstered arguments that positive classroom perceptions and teacher support affected students' motivation in math. Mirza and Hussain (2014) stated that the best math teachers have always encouraged their students.

In this study, students indicated that encouragement and support from their teachers was more motivating than other enablers of motivation. This perception from my students agrees with previous research from Kiefer et al. (2015), Nenthien and Loima (2016), and Yurt (2015). During interactions with students, particularly their answers during the focus group interview, students pointed out the importance of their teacher as an important factor to their motivation in math. This observation agreed with assertions by Hornstra et al. (2018) that teachers' praise can instill belief in students that they are competent at completing tasks. Students in this study stated that "teachers affect the mood" and have to be "motivated to teach". My students indicated that teachers could "change your whole attitude that day." Additionally, students pointed out that motivation could be hindered by bad teachers. In agreement with Mirza and Hussain (2014) above, my students noted that great math teachers motivate them by providing encouragement. It was a very strong reassurance of my purpose in life. It reminded me that teachers can affect students' lives in positive ways.

Implications

Even though action research is not generalizable to the population at large, the rigor of data collection and analysis produces results that have implications for various stakeholders in the population. This action research study has implications for practice within my own classroom. It also has implications for teaching high school Algebra courses. Finally, there are implications for future research that could take place in my classroom, or others' classrooms. The section will be divided into the following sections:

(a) personal implications, (b) implications for teaching high school Algebra, and (c) implications for future research.

Personal Implications

After completing this action research, I discovered three major implications for instructional design in my classrooms. These implications include the importance of (a) utilizing action research methods in classrooms, (b) varying instructional design strategies, and (c) motivating my students with encouragement and effort.

Utilizing action research methods in classrooms. My goal as an educator is to be a continual learner about my subject and instructional practice. However, my goal has not always aligned with my actions in classrooms. Although I have changed portions of my instructional design on various occasions, I have never truly analyzed the results with the same rigor utilized in this study. The action research process provided me with the opportunity to change the instructional design of my classroom with higher intentionality. Additionally, I documented personal observations, student observations, and quantitative data. These data gave me a more complete picture of the effects my instruction was having in my classroom.

As the name action research suggests, it encourages researchers to actively affect or examine change in their context. Action research also encourages researchers to implement multiple iterations of their research to refine their intervention measures and improve their practice. This action research process has altered my view of instructional changes within the classroom. It has provided me with evidence of how changing traditional structure in math classrooms affects my students. It has also expanded my knowledge and use of both quantitative and qualitative data sources. In the past, I have relied on each separately. Mixed methods action research provided me with the necessary skills to analyze and process a more complete picture of what is happening when I make a change in my classroom (Creswell & Creswell, 2018).

Varying instructional design strategies. I have implemented a variety of class instructional changes throughout my career. However, it has typically been single lessons, or activities. For this action research, implementing instructional change for a much longer period of time challenged my time management skills and relinquishing control in my classroom. Utilizing problem-based learning in a flipped classroom generated a more student-centered class environment. More specifically, problem-based learning provided my students with real-world tasks that were engaging, relevant, and high value for the students. This research experience has reinforced the need for constant improvement in my instructional approach to mathematics within my classes. Combining the cyclical nature of action research and instructional design models should create a constant development of my classroom instruction (Mertler, 2019; Morrison et al., 2013).

Motivating my students with encouragement and effort. Throughout my qualitative data sources, my students indicated that my effort and encouragement was more motivating to them than other influences. For example, Catherin Klyment explained, "You just never know what's going on outside of school. And like, with that teacher being there, actually motivated, can change your whole attitude that day." Catherin declared that my effort and encouragement could counteract matters of life that were affecting her motivation. Loren Paul said, "I can say without a doubt that my teacher is passionate about his career, truly wanting only the best futures for his students, and giving us the knowledge to achieve success." Students knew that I cared about them and was giving my complete effort in class; therefore, they were motivated to give more effort in class. My students implied that the teacher was extremely important for motivating their students. Even though students realized the effect of other influences to their motivation, they longed for a teacher that was passionate and hard-working. This finding has reminded me of the importance of continuing to teach and encourage my classes with passion. Teachers are responsible for creating a positive classroom environment and motivating their students.

Implications for Teaching High School Algebra

At the conclusion of this action research, three major implications were revealed for high school Algebra classrooms. All three implications were interrelated to each other and provide Algebra teachers with advice for their classrooms. The implications were (a) students appreciate traditional lesson structure while learning mathematics, (b) students experience high-value real-world tasks through problem-based learning, and (c) problem-based learning in a flipped classroom cannot be the sole instructional design of an Algebra course.

Students appreciated traditional lesson structure while learning mathematics. Even though my students' beginning survey answers claimed that they wanted math class to be only activities instead of normal instruction, students made it clear through journal and focus group interview responses that they also wanted traditional math instruction. This implication is grounded in two primary reasons. First, students indicated that problem-based learning was consuming time that could have been spent practicing math skills. Keller (1987) has suggested that students are more motivated if their lessons increase their confidence in subject matter. Students in my class felt that the time spent on problem-based learning was inhibiting their math practice, and thus their confidence in mathematics was waning. Due to their desire to be successful, students asked for more practice in a traditional structure. Students were not disappointed with problem-based learning. However, they were more aware of their need to practice math skills under more direct instruction.

Additionally, students were not always willing to spend the time that was required to go above and beyond the traditional math instruction. Jiang et al. (2018) pointed out that cost was the negating component of motivation to complete a task, where the pursuit required more effort than someone was willing to give. Problem-based learning in a flipped classroom required students to do more work than they were accustomed to in traditional instruction. Magliaro et al. (2005) pointed out that direct instruction has been beneficial to teach content, processes, and skills in a succinct manner. Students in my class realized that they still desired to have more traditional instructional styles in Algebra, even though they claimed the opposite at the beginning of my course.

Students experienced high-value real-world tasks through problem-based learning. Even though my students did develop a higher appreciation for traditional direct instruction in mathematics, they also realized the value of the problem-based learning experience. Students were able to experience engaging real-world tasks throughout the problem-based learning portion of my innovation. Alina Hadley stated, “But, you really, like, showed us that, like, it actually applies to the real world, not in just like small little areas, but like overall big, big things that we have to worry about.” Problem-based learning was expanding students’ learning beyond the Algebra classroom. Alina also mentioned during our Business Plan PBL that she could finally understand the need to satisfy multiple variables in math, which helped to motivate her to understand Systems of Equations to a more complete degree. Loren Paul explained, “This year’s Algebra 2 course was very different from your traditional high school math class. We spent a great deal of time applying what we learned to scenarios that will come about in our futures.” The problem-based learning experience reinforced the relevance category of the ARCS model for designing instruction (Keller, 1987).

Problem-based learning in a flipped classroom cannot be the sole instructional design of an Algebra course. Combining the findings from the previous implications, teachers can form a classroom that utilizes multiple instructional design strategies in Algebra. Algebra teachers can utilize problem-based learning to engage students in real-world scenarios. Students can take an active role in their learning. However, teachers also need to employ direct instruction for higher level Algebra content, processes, and skills. There are Algebra topics that do not lend themselves to discovery by ill-structured problems that are the nature of problem-based learning. Therefore, problem-based learning cannot be the sole source of instruction in high school Algebra classrooms.

Implications for Future Research

Finally, this research provided two major implications for future research in math classrooms. Motivation is still a concern due to the fact that there was not a significant increase in my students’ motivation scores. First, research should be conducted on limiting the cost influence on students’ motivation in math. Finally, research should be conducted that creates a balanced approach to instructional design and measures its impact on motivation and achievement.

Cost as an influence on motivation. Motivation is the driving force behind what individuals choose to do and what makes them sustain effort (Dimitroff et al., 2018; Keller, 1987; Yurt, 2015). For this study, motivation was defined as an intrinsic or extrinsic force that initiates, guides, and sustains activities or behaviors aimed at achieving a goal. One of the major findings from this action research was that overall motivation scores did not significantly increase on my Motivation in Mathematics Survey. The primary reason for this finding was the subscale that measured the motivational category of cost. Cost is defined by Jiang et al. (2018) as the "negative consequences of engaging in a task" (p. 140). Further research into limiting this factor would be beneficial to teachers of mathematics.

My students indicated that their primary cost concerns were the time required to complete math assignments and the rapidly approaching spring and summer break. The nature of my study, which included problem-based learning in a flipped classroom, forced students to complete assignments that went above and beyond Algebra assignments alone. Decreasing the time required to complete math assignments could be as simple as completing the same study with fewer assignments that students need to complete. Redesigning the study to include fewer problem-based learning experiences would still realize the benefits of PBL and minimize the cost of more required time. Another possible avenue for further research would be attempting to minimize the work that is required at home. Research suggests that homework improves achievement, should be adjusted according to complexity, and is under debate for the ideal amount (Cooper, Robinson, & Patall, 2006; Güven & Akçay, 2019; Trautwein, 2007). Due to my students' concern of the impending spring and summer break affecting their motivation, another area of further research would be changing the time of school year that problem-based learning in a flipped classroom was implemented.

Two other suggestions are directly related to my own shortcomings during the study. The first is improving my own time management during school hours to facilitate students needing less of their own time at home. Second, my students indicated that many of my videos for flipped lessons became too lengthy. Better time management within my videos would lessen the impact on students' time at home. Gaughan (2014) utilized videos that were no longer than 40 minutes, but planned to shorten videos to no longer than 15 minutes after student complaints. Educators that are interested in further research can learn from my video length mistakes. I can also adjust future iterations of my own action research.

Balanced instructional design. For this study, my instructional design was to begin the semester with traditional mathematics instruction and measure student motivation preinnovation. Then, students would participate in problem-based learning in a flipped classroom before having their motivation measured postinnovation. Ghufron and Ermawati (2018) noted that problem-based learning has required more time than a traditional lesson. My students noted that problem-based learning consumed time that would normally be used to practice math skills. Lack of practice on math skills led to a lack of confidence in my students, and consequently, their motivation in math. I also observed that students were frustrated with their perceived lack of math skills, even though they were experiencing engaging real-world problems. Furthermore, students were frustrated with the amount of time on flipped lessons at home. I also noted that the problem-based learning experiences interfered with one of the benefits of flipped lessons: extra practice with teacher feedback in class.

After reading my perceptions and my students' perceptions, it was clear that we thought the innovation period was extremely demanding on time. Problem-based learning implements relevant and engaging tasks, which should improve student motivation (Keller, 1987). However, it does not always lend itself to learning traditional skills in a subject like Algebra (Barrows & Tamblyn, 1980). Traditional instruction can combat against this weakness. I thought that the flipped classroom would provide time for both problem-based learning and direct instruction, as well its own benefits. The combination of the various methods of instruction might have been the reason students' motivation did not improve. This corroborates the evidence of students claiming that the cost of doing math was too high. Cost was the subscale on my Motivation in Mathematics survey that actually decreased in mean score. Designing the research so that the differing instructional methods are separated into more distinct units could impact some of the negative findings from my research. Motivation could also be measured under this different type of instructional design.

Limitations

Any research study can be subject to weaknesses and deficiencies. Therefore, I evaluated my own study for possible points of failure that affected the study and could be improved upon. The limitations for my study constitute three major categories that are discussed below: (a) researcher participant limitations, (b) sample limitations, and (c) student participant limitations.

Researcher Participant Limitations

Due to the nature of my action research examining an innovation in my classroom practice and measuring its impact, I was also an active participant within the study. Action research with participant researchers can have unintended effects on the study (Greenwood & Levin, 2007; Mertler, 2019). My participation as the teacher and the researcher affected my data collection. While I did have a wealth of quantitative and qualitative data, I know that I would have been able to obtain more data, if I was not an active participant in the study. Specifically, my observation notes would contain even more detail than already present. I also would have had more opportunities to hear more students' responses in the middle of problem-based learning. My quantitative data and qualitative data provided a rich explanation of the results, but more data could have provided an even more complete picture.

Another limitation of being an active participant is the affect that I may have had on my students' motivation survey responses and focus group interview responses. When someone in authority over students is also the observer of their responses, students may answer in a way that they feel will please the observer. The mere presence of an observer could alter the thing being observed (Rudestam & Newton, 2007). Students were aware of the nature of my study. They participated in a preinnovation and postinnovation survey about their motivation in math. There is a possibility that some students provided their Likert scale responses based on what they thought I wanted to hear. The preinnovation measure making students aware of what is being studied could contaminate the validity of the postinnovation measure (Rudestam & Newton, 2007). The same situation could have happened during the focus group interview. I attempted to combat against students answering dishonestly by building rapport with the students based on honesty from them and myself as a listener. However, students attempting to please me with their responses is a concern due to the nature of the study.

Sample Limitations

Action research within a single classroom also has limitations imposed by the sampling of students. First, executing the research method on one classroom for my innovation naturally limited the sample size to only 22 students. While limited size and representation does prevent generalizability to the population at large, readers can still determine the merits of my research findings by my methods and rigor (Mertler, 2019). This limited sample size also led to a reduction in data obtained from the students. Getting students to complete assignments can be a challenge. Therefore, I was unable to get every student to complete every single journal entry. As mentioned previously, I still had a wealth of qualitative data, but would have been better-off with more.

For my study, I also chose to use a College Prep (CP)-level class. CP-level students typically have a much more diverse background in prerequisite courses compared to Honors-level students. Their experiences range from remedial to Tech-Prep to CP. Therefore, they also have a variety of levels of success with math that can affect their motivation as well (Hornstra et al., 2018; Mkhize, 2017). Although performing the study in an Honors-level class would have a sampling of students with more homogeneity, the better option may be to have both levels of class as participants. This study design would also provide more quantitative and qualitative data.

Student Participant Limitations

Several limitations were directly related to students as participants. Specifically, students did not participate in 100% of the activities that were incorporated into my innovation. Some students chose not to practice in class or participate in the various problem-based learning experiences. It was not always the same students, so it did not severely limit the effectiveness of the study, but 100% participation would be ideal. One particular weakness of the flipped classroom that limited my study is students not watching videos at home (Gaughan, 2014). These limitations were exacerbated by the small sample size mentioned previously.

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APPENDIX A

MOTIVATION IN MATHEMATICS SURVEY

The following questions ask about your motivation for and attitudes about this class. Remember, there are no right or wrong answers; just answer as accurately as possible. Use the scale below to answer the questions. If you think the statement is very true of you, circle 7; if a statement is not at all true of you, circle 1. If the statement is more or less true of you, find the number between 1 and 7 that best describes you.

1	2	3	4	5	6	7
not at all true of me			somewhat true			very true of me

Self-efficacy

1. I'm certain that I can understand what is taught in math class.

2. I expect to do very well in math class.

3. I am sure that I can do an excellent job on the problems and tasks assigned for math class.

4. I know that I will be able to learn the material for math class.

5. My study skills are excellent in math class.

6. I think I will receive a good grade in math.

Task value

1. I think I will be able to use what I learn in math class in other places.

2. I think math is useful for me to learn.

3. Understanding math is very important to me.

4. It is important for me to learn math.

5. I am very interested in math.

6. I like math.

Cost

1. Doing well in math requires more effort than I want to put into it.

2. It requires too much effort for me to get a good grade in math.

3. It takes too much of effort for me to do well in math.

4. I have to give up other activities that I like to do well in math.

5. I have to sacrifice a lot of free time to be good at math.

6. To do well in math requires that I give up other activities I enjoy.

7. Others would think worse of me if I failed to do well in math.

8. Others would think I am incompetent if I get low grades in math.

9. Others would be disappointed in me if I performed poorly in math.

10. Studying math scares me.

11. Studying math makes me feel stress.

12. Studying math makes me annoyed.

Positive classroom affect

1. Most of the time, being in math class puts me in a good mood.

2. I like being in math class.

3. I am happier when I am in math class than when I am in other classes

APPENDIX B

STUDENT JOURNAL PROMPTS

Student Journal Entry 2/22/22
For your journal today, tell me about your experiences in math class this week.

You can think about the following prompts, but feel free to tell me whatever you truly think:
1. This week in math class, I worked as hard as I could because…
2. Math class was fun/boring this week because…
3. I enjoyed thinking about math this week because…
4. This week, it was important for me to understand the math because…
5. I tried to learn as much as I could this week because…
6. Math was interesting for me this week because…
7. I liked the feeling of solving problems this week because…

How would you evaluate your problem-solving process for your Business Plan? What did you do well? What do you need to improve?

What was one important thing that you learned through the problem experience?

Student Journal Entry 3/4/22
For your journal today, tell me about your experiences in math class this week.

You can think about the following prompts, but feel free to tell me whatever you truly think:
1. This week in math class, I worked as hard as I could because…
2. Math class was fun/boring this week because…
3. I enjoyed thinking about math this week because…
4. This week, it was important for me to understand the math because…
5. I tried to learn as much as I could this week because…
6. Math was interesting for me this week because…
7. I liked the feeling of solving problems this week because…

How would you evaluate your problem-solving process for your Student App? What did you do well? What do you need to improve?

What was one important thing that you learned through the problem experience?

Student Journal Entry 3/18/22
For your journal today, tell me about your experiences in math class this week.

You can think about the following prompts, but feel free to tell me whatever you truly think:

1. This week in math class, I worked as hard as I could because…
2. Math class was fun/boring this week because…
3. I enjoyed thinking about math this week because…
4. This week, it was important for me to understand the math because…
5. I tried to learn as much as I could this week because…
6. Math was interesting for me this week because…
7. I liked the feeling of solving problems this week because…

How would you evaluate your problem-solving process for your Global Warming and Industrialization Problem? What did you do well? What do you need to improve?

What was one important thing that you learned through the problem experience?

Student Journal Entry 3/25/22

Tell me about your experience during math overall this semester. I am not giving you a prompt here, because I want you to feel free to tell me your thoughts. Please, do not hold anything back. Be completely honest.

What are your feelings towards math? Are you more, or less motivated, to do math after this semester?

Student Journal Entry 4/8/22

Tell me about your transition from problem-based learning in a flipped classroom back to more traditional math instruction. Give me your complete thoughts.

Do you feel that your motivation has decreased? If so, is this due to instruction, or due to impending Spring Break?

~~spacer~~

APPENDIX C

FOCUS GROUP INTERVIEW QUESTIONS

First of all, thank you all for being willing to participate in my study. Thank you for interacting with math in a different way during this experience. During this interview, please answer questions honestly. Do not try to answer in a way that you think would please me. I want to know your true feelings. Some questions will be to specific people, but feel free to join in the conversation.

The approximately hour-long interview will be recorded. If you want me to stop the recording at any time, please tell me to do so. I will also be taking notes to ensure accurate data. Are there any questions before we begin?

Formal Interview Questions:
Please give a short description of your overall experience during problem-based learning in a flipped classroom.

What is problem-based learning?

What is a flipped classroom?

Do you feel like you were able to learn the topics in this math course? Why or why not?

Did you put in the required amount of time to succeed in this course? Tell me how much time you needed to devote to this course.

Describe the usefulness of math to other courses and the real-world.

What do you think motivation means? Follow-up: Does motivation come from inside you, or does something external motivate you?

Are you motivated to succeed in mathematics? Why or why not?

What are things that keep you from being motivated in math class?

Several of you, [names mentioned here], made observations during our flipped classroom experience that some videos were too long and the work outside of the classroom was more than you expected. How did this affect your motivation in math class or your ability to learn the topics?

[name here], I know that you said you miss the videos now. What are some of the reasons that you liked having the videos?

What causes you to find enjoyment in math? How do you think problem-based learning in a flipped classroom affects your enjoyment?

Who is responsible for your math grade in this course? What other factors may influence your grade?

Why is this course important?

[name here], you mentioned one day during our problem-based learning that it helped you to see where math could be used in a real-world scenario. Do you think that all students would benefit from these experiences, and why?

How has problem-based learning changed the way you think about math?

According to research, students will be more motivated if lessons access the following categories: Attention, Relevance, Confidence, and Satisfaction. Which of these categories did you notice during our experience? Do you think that these categories would be accessed in traditional math instruction?

Are you more or less motivated to succeed now and why?

Tell me any more information that I need to know.

Again, thank you so much for your participation during this interview.

APPENDIX D

DIAGNOSTIC TEST ON SYSTEMS OF EQUATIONS AND QUADRATIC FUNCTIONS

1.

Solve the system of equations. Enter your answer as an ordered pair.

$$\begin{cases} 4x + y = -1 \\ -5x - 2y = -4 \end{cases}$$

solution = __________

2.

Solve the system of equations.

$$\begin{cases} x + y + z = 9 \\ -2x + y + 2z = 3 \\ x - 4y - z = 2 \end{cases}$$

○ A. (0, 15, −6)

○ B. (3, 3, 3)

○ C. (4, −1, 6)

○ D. (7, 1, 1)

3.

Part A

Shandra is on vacation and wants to buy souvenirs for at least eight friends.
A postcard book costs \$2.50 and a magnet costs \$4.00. She can spend up to \$30 all together.
Which system of inequalities represents the situation?

○ A. $\begin{cases} x + y \leq 8 \\ 2.5x + 4y \geq 30 \end{cases}$

○ B. $\begin{cases} x + y \geq 6.50 \\ 2.5x + 4y \leq 30 \end{cases}$

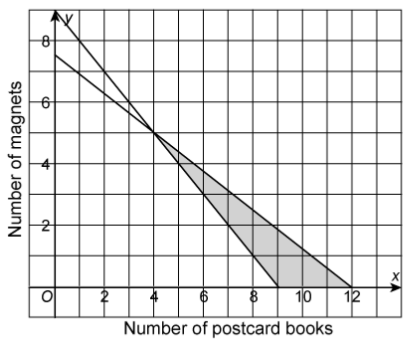
○ C. $\begin{cases} x + y \geq 9 \\ 2.5x + 4y \leq 30 \end{cases}$

○ D. $\begin{cases} x + y \geq 8 \\ 2.5x + 4y \leq 30 \end{cases}$

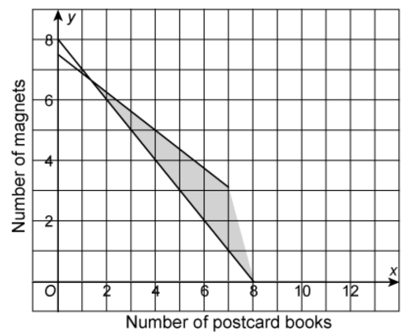
Part B

Which graph represents the system?

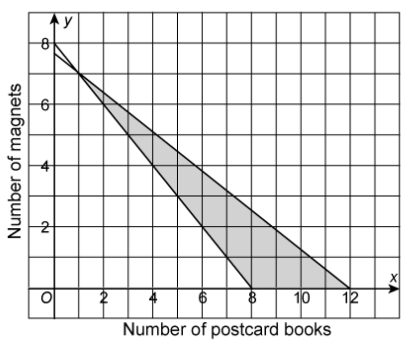
○ A.



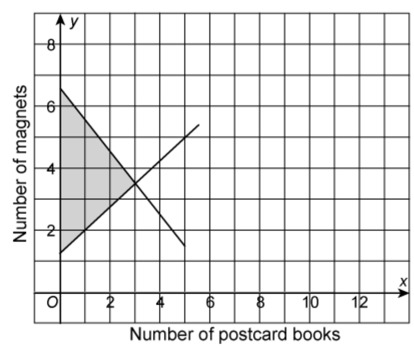
○ B.



○ C.



○ D.



4.

Use substitution to solve the system $\begin{cases} y = -\frac{1}{2}x^2 \\ y = x - 4 \end{cases}$.

- A. −4 and 2
- B. (4, −8) and (−2, −2)
- C. (−4, −8) and (2, −2)
- D. (0, 0) and (0, −4)

5.

Nate tosses a ball up a hill for his dog to chase. The path of the ball is modeled by the function $y = -\frac{1}{4}x^2 + \frac{33}{5}x$, where *x* is the ball's horizontal distance from Nate in feet and *y* is the ball's height in feet. The hill is modeled by the line $y = \frac{1}{5}x$. How far does the ball travel horizontally before it hits the ground?

- A. 25.6 feet
- B. 26.4 feet
- C. 13.2 feet
- D. 12.8 feet

6.

Solve $|x + 3| - 1 = (x + 2)^2$ by graphing.

The solutions are $x =$ ______ and $x =$ ______ .

7.

Over what interval is the graph of $y = 2 + (x - 3)^2$ increasing?

- A. $(-3, \infty)$
- B. $(-\infty, 3)$
- C. $(-\infty, -3)$
- D. $(3, \infty)$

8.

Identify the translations of the parent function $f(x) = x^2$ that give $g(x) = (x - 5)^2 - 4$.

- A. up 4 units, left 5 units
- B. up 4 units, right 5 units
- C. down 4 units, left 5 units
- D. down 4 units, right 5 units

9.

Primo car rental agency charges \$49 per day plus \$0.20 per mile. Ultimo car rental agency charges \$26 per day plus \$0.85 per mile. Find the daily mileage for which the Ultimo charge is four times the Primo charge.

The mileage is ☐.

10.

What is the equation written in vertex form of a parabola with a vertex of (–1, 8) that passes through (1, 0)?

- A. $y = (x + 1)^2 + 8$
- B. $y = 2(x - 1)^2 - 8$
- C. $y = 2(x + 1)^2 - 8$
- D. $y = -2(x + 1)^2 + 8$

11.

Function g is a transformation of the parent function $f(x) = x^2$. The graph of g is a translation left 4 units and down 2 units of the graph of f. Write the equation for g in the form $y = ax^2 + bx + c$.

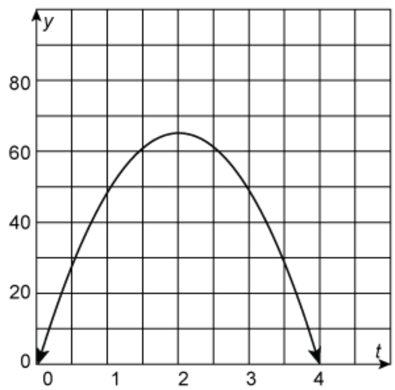
- A. $y = x^2 + 8x + 18$
- B. $y = x^2 + 8x + 14$
- C. $y = x^2 - 8x + 18$
- D. $y = x^2 - 8x + 14$

12.

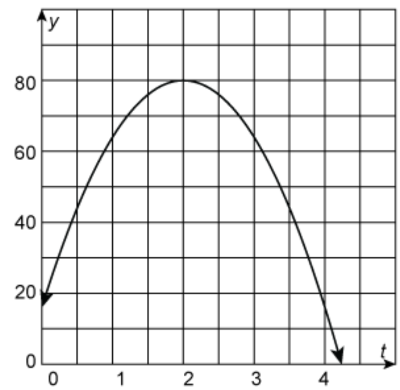
Part A

The path of a projectile launched from a 16-ft-tall tower is modeled by the equation $y = -16t^2 + 64t + 16$. Which is the correct graph of the equation?

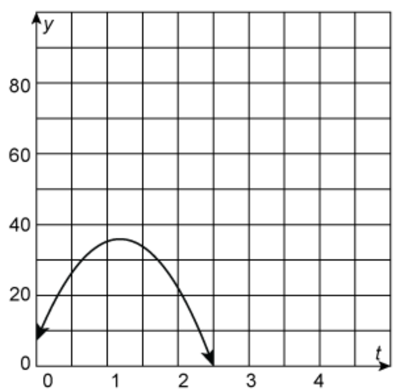
○ A.



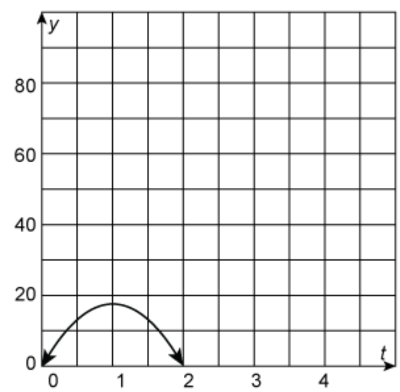
○ B.



○ C.



○ D.



Part B

The path of a projectile launched from a 16-ft-tall tower is modeled by the equation $y = -16t^2 + 64t + 16$. What is the maximum height, in feet, reached by the projectile?

The maximum height is ______ feet.

13.

Solve the equation $x^2 + x = 12$.

○ A. $x = -3$ and $x = -4$

○ B. $x = 2$ and $x = -6$

○ C. $x = -2$ and $x = -6$

○ D. $x = 3$ and $x = -4$

14.

A ball is thrown from the top row of seats in a stadium. The function $h(t) = -16t^2 + 64t + 80$ gives the height, h, in feet, of the ball t seconds after it is thrown. How long will it be before the ball hits the ground?

The ball will hit the ground after ____ seconds.

15.

Identify the interval(s) on which the function $y = x^2 - 2x - 48$ is positive.

- A. $x < -6$ and $x > 8$
- B. $-6 < x < 8$
- C. $x > 6$ and $x < -8$
- D. $6 < x < 8$

16.

Write the product $(4 + i)(4 - i)$ in the form $a + bi$.

- A. $16 - i$
- B. $16 - i^2$
- C. 17
- D. 8

17.

Solve $0 = x^2 - 10x + 30$ by completing the square.

- A. $x = 5 + i$ and $x = 5 - i$
- B. $x = 5 + i\sqrt{5}$ and $x = 5 - i\sqrt{5}$
- C. $x = -5 - i\sqrt{6}$ and $x = -5 + i\sqrt{6}$
- D. $x = -5 - i\sqrt{5}$ and $x = -5 + i\sqrt{5}$

18.

A function is defined by the equation $y = x^2 + 3x + 1$. Which statements are true? Select all that apply.

- ☐ A. The equation written in vertex form is $y = \left(x + \frac{3}{2}\right)^2 - \frac{5}{4}$.
- ☐ B. The equation written in vertex form is $y = \left(x + \frac{5}{4}\right)^2 - \frac{3}{2}$.
- ☐ C. The graph of the function has a minimum of $y = -\frac{5}{4}$ at $x = -\frac{3}{2}$.
- ☐ D. The domain of the function is all real numbers.

19.

Solve $x^2 + 3x + 4 = 0$ using the Quadratic Formula. Select any solutions that apply.

- ☐ A. $x = \frac{-3 + i\sqrt{7}}{2}$
- ☐ B. $x = \frac{-3 - i\sqrt{7}}{2}$
- ☐ C. $x = \frac{-3 + \sqrt{7}}{2}$
- ☐ D. $x = \frac{-3 - \sqrt{7}}{2}$

20.

Solve $x^2 - 7x + 5 = 0$ using the Quadratic Formula.

- ○ A. $x = \frac{7 + \sqrt{29}}{2}$ and $x = \frac{7 - \sqrt{29}}{2}$
- ○ B. $x = 7 + \sqrt{29}$ and $x = 7 - \sqrt{29}$
- ○ C. $x = -5$ and $x = -1$
- ○ D. $x = \frac{7 + \sqrt{69}}{2}$ and $x = \frac{7 - \sqrt{69}}{2}$

21.

Part A

A toy cannon ball is launched from a cannon on top of a platform. The equation $h(t) = -5t^2 + 20t + 4$ gives the height h, in meters, of the ball t seconds after it is launched. What equation can be used to tell whether the ball reaches a height of 12 m?

- A. $-5t^2 + 20t + 4 = 0$
- B. $-5t^2 + 20t + 4 = 12$
- C. $-5t^2 + 20t + 4 + 12 = 0$
- D. $-5t^2 + 20t + 4 = t + 12$

Part B

A toy cannon ball is launched from a cannon on top of a platform. The equation $h(t) = -5t^2 + 20t + 4$ gives the height h, in meters, of the ball t seconds after it is launched. Does the ball reach a height of 12 m?

- A. yes
- B. no

22.

Determine the number of real solutions of the system $\begin{cases} y = x^2 + 8 \\ y = x + 15 \end{cases}$

- A. 0
- B. 1
- C. 2
- D. 3

23.

Solve the equation $-3x^2 + 2x + 4 = -x - 3$ by writing a linear-quadratic system and solving using the intersection feature of a graphing calculator. Round to the nearest hundredth.

- A. $x \approx -2.44$ and $x \approx 3.12$
- B. $x \approx -1.63$ and $x \approx 4.43$
- C. $x \approx -1.11$ and $x \approx 2.11$
- D. $x \approx -2.61$ and $x \approx 0.42$

24.

Which of the following statements describe key features of the graph of $f(x) = -x^2 - 2x + 3$? Select all that apply.

- ☐ A. The y-intercept is (0, 3).
- ☐ B. The vertex is (−1, −4).
- ☐ C. The equation of the axis of symmetry is $x = -1$.
- ☐ D. The vertex is (−1, 4).

25.

A pebble is tossed into the air from the top of a cliff. The height, in feet, of the pebble over time is modeled by the equation $y = -16x^2 + 32x + 80$. What is the maximum height, in feet, reached by the pebble?

The maximum height is ______ feet.

26.

What is the equation of a parabola that passes through the points (−5, −10), (−3, 2), and (2, −3)?

- ○ A. $y = -x^2 - 2x + 5$
- ○ B. $y = -x^2 + 6x - 7$
- ○ C. $y = -\frac{18}{9}x^2 - \frac{28}{9}x + \frac{35}{3}$
- ○ D. $y = -x^2 - 3x + 2$

27.

Use quadratic regression to find the equation of a quadratic function that fits the given points.

x	0	1	2	3
y	29	42	62	38

- ○ A. $y = -8.52x^2 - 16.72x + 23.47$
- ○ B. $y = -9.25x^2 + 32.45x + 26.45$
- ○ C. $y = 3.5x^2 - 9.5x + 29$
- ○ D. $y = 8.52x^2 + 16.72x + 14.47$

28.

Solve $x^2 - 18x + 81 = 4$ by completing the square. Select any solutions that apply.

- ☐ A. $x = -11$
- ☐ B. $x = -7$
- ☐ C. $x = 7$
- ☐ D. $x = 11$

29.

Describe the nature of the roots for the equation $49x^2 - 28x + 4 = 0$.

- ○ A. two real roots
- ○ B. one real root
- ○ C. two complex roots
- ○ D. one complex root

30.

The function $g(x) = (x + 2)^2 + 4$ is a transformation of the parent function $f(x) = x^2$. Which of the following statements are true? Select all that apply.

- ☐ A. Function g is the result of f being translated right 2 units and down 4 units.
- ☐ B. Function g is the result of f being translated left 2 units and up 4 units.
- ☐ C. The graph of function f opens upward.
- ☐ D. The graph of function f opens downward.
- ☐ E. The graph of function f is compressed by a factor of 2.

31.

What are the domain and range of the function $h(x) = -\frac{1}{2}(x - 4)^2 + 3$?

- ○ A. The domain is all real numbers and the range is $y \leq 3$.
- ○ B. The domain is $x \geq 4$ and the range is $y \geq 3$.
- ○ C. The domain is all real numbers and the range is $y \geq 3$.
- ○ D. The domain is $x \geq -4$ and the range is $y \leq -3$.

32.

Select the factored form of the expression $3x^2 - 11x - 4$.

- A. $(3x - 4)(x + 1)$
- B. $(3x - 2)(x + 2)$
- C. $(3x + 1)(x - 4)$
- D. $(3x - 1)(x + 4)$

33.

Solve the equation $x^2 + 7x = 30$.

- A. $x = 15$ and $x = -2$
- B. $x = -6$ and $x = 5$
- C. $x = -10$ and $x = 3$
- D. $x = 10$ and $x = -3$

34.

Write the equation of a parabola with x-intercepts at (3, 0) and (9, 0) that passes through the point (10, −7).

- A. $y = -x^2 + 12x - 27$
- B. $y = -3x^2 + 4x - 9$
- C. $y = 3x^2 - 4x + 9$
- D. $y = x^2 - 12x + 27$

35.

Identify the interval(s) on which the function $y = x^2 + 12x + 27$ is positive.

- A. $-9 < x < -3$
- B. $x < -9$ and $x > 3$
- C. $x < 3$ and $x > 9$
- D. $x < -9$ and $x > -3$

APPENDIX E

IRB APPROVAL LETTER

UNIVERSITY OF
SOUTH CAROLINA

OFFICE OF RESEARCH COMPLIANCE

INSTITUTIONAL REVIEW BOARD FOR HUMAN RESEARCH
DECLARATION of NOT RESEARCH

Joshua Harrison
150 Blue Flame Dr.
Pickens, SC 29671

Re: **Pro00117723**

Dear Mr. Joshua Harrison:

This is to certify that research study entitled ***The Effects of Problem-Based Learning on Mathematics Motivation in a Hybrid Technology-Mediated Instructional Environment*** was reviewed on **12/14/2021** by the Office of Research Compliance, which is an administrative office that supports the University of South Carolina Institutional Review Board (USC IRB). The Office of Research Compliance, on behalf of the Institutional Review Board, has determined that the referenced research study is not subject to the Protection of Human Subject Regulations in accordance with the Code of Federal Regulations 45 CFR 46 et. seq.

No further oversight by the USC IRB is required. However, the investigator should inform the Office of Research Compliance prior to making any substantive changes in the research methods, as this may alter the status of the project and require another review.

If you have questions, contact Lisa M. Johnson at lisai@mailbox.sc.edu or (803) 777-6670.

Sincerely,

Lisa M. Johnson
ORC Associate Director and IRB Manager

University of South Carolina ● 1600 Hampton Street, Suite 414 ● Columbia, South Carolina 29208 ● 803-777-7095
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