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ABSTRACT

The purpose of this action research study is to explore how learners and the instructor experience learning Calculus One (Calculus I) when active learning is implemented in a face-to-face and virtual classroom. As such this was a flipped classroom, so chosen because the National Council of Teachers of Mathematics recommended changing traditional methods to an approach that utilizes a more constructivist approach that promotes active learning. The theoretical framework for the analysis was grounded in constructivism and supported by a community of mathematical inquiry. The study used an action research methodology that makes use of an ongoing cycle of planning, acting, observing, and reflecting while collecting and analyzing data as the course and study unfolded. It took place in a Calculus 1 class in the Spring 2020 over a 15-week semester. The first half of the class was face-to-face but due to COVID 19 the second half took place over Zoom. Data collection consisted of questionnaires, minute papers, end of semester interviews, researcher journal, and faculty evaluations.

Given the unexpected challenges of COVID 19 and its required move to remote teaching in the second half of the class, the findings of the study were grouped into two chapters: one on the face-to-face flipped classroom and the other on the virtual flipped classroom. While students faced many challenges in the virtual classroom, they acknowledged that both flipped learning environments provide ways to improve peer-to-peer collaboration, support student-to-teacher interaction, and increase student responsibility in learning. Data analysis resulted in findings also indicate that flipped learning engages students in active dialogue, increases mathematical discourse and creates a community of mathematical inquiry. The dissertation concludes by highlighting implications for theory, practice, and further research.
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CHAPTER 1

INTRODUCTION

This chapter provides an overview of an action research study focused on an flipped classroom approach in teaching calculus in a face-to-face and virtual classroom. After I began to collect data in early 2020, the novel coronavirus disrupted face-to-face sessions half-way through the course. In early March, as the situation became increasingly urgent by the higher education institutions, the administration decided to cancel all face-to-face classes for the rest of the semester and asked students to finish their courses in constructed online versions. This was overwhelming for students and also myself.

I should admit that this made me nervous. I had prepared and planned my research project for a face-to-face course, and I was so excited to do so. But the COVID-19 (an illness caused by a virus that can spread from person to person) has introduced a wide array of challenges, and I had to substantially change the way I had designed my course and my research to accommodate online delivery. Online teaching is not novel and has existed for some time now. As a means to deliver classes, online instruction can accommodate various distances and different student schedules. What made online teaching delivery a bit different in spring 2020 was that the students were not online learners but rather members of the active, on-campus students, and now they had to learn remotely.

Even though it was challenging, due to the flexibility of action research, I was able to expand my research into the effects of online synchronous instruction using the flipped classroom and to compare and contrast what worked. I continued to collect data while switching to a Zoom classroom. This enabled me to understand how active learning works in a flipped course using Zoom technology to create a dynamic environment.
This chapter provides an overview of an action research study focused on a flipped classroom approach in the face-to-face and the virtual calculus classroom. A flipped classroom is a pedagogical model in which a classroom is transformed into a more interactive learning environment wherein the educator guides students as they apply concepts and engage creatively in the subject matter. This chapter includes the background of the study, the problem statement, the purpose and research questions, an overview of the theoretical framework, and the research methodology. The chapter concludes with definitions, assumptions, and limitations of the research.

**Background of the Problem**

The need for professionals (and therefore, students) in the fields of science, technology, engineering, and mathematics (STEM) is growing faster than we, in the United States, are producing them. According to a 2012 report by the President’s Council of Advisors on Science and Technology (PCAST), the job market will experience a deficit of one million STEM graduates through 2022. Despite the overwhelming demand for STEM graduates, retention of students in STEM higher education has been a challenge (Bressoud, Mesa, & Rasmussen, 2015; PCAST 2012; Rasmussen & Ellis, 2013; Seymour, 2006). Students who leave a STEM major complain about having been frustrated with some courses such as calculus. Calculus courses are required for many diverse STEM-related disciplines and have made STEM degrees difficult for many students to obtain (Bressoud, 2015). Disappointing experiences in beginning calculus are one of the more frequently cited reasons students give for changing their majors or leaving STEM fields (Petrillo, 2016; Rasmussen & Ellis, 2013; Seymour, 2006). Calculus is a gateway course and is known for its high failure and attrition rates. The ability to successfully master
calculus is a predictor of success in STEM fields (Bressoud et al., 2015; PCAST, 2012; Petrillo, 2016; Rasmussen & Ellis, 2013; Sonnert, Sadler, Sadler, & Bressoud, 2015).

Calculus I, in particular, is one of the most challenging STEM introductory courses. This is perhaps due to the abstract nature of calculus and to the level of critical thinking and problem solving required, “the course content is unavoidably difficult” for students (Petrillo, 2016, p. 573). Students’ lack of understanding of the mathematical concepts interferes with their problem-solving abilities, particularly in being able to solve non-routine problems (Dawkins & Mendoza Epperson, 2014; Gordon, 2004), though many of them are capable of solving challenging exercises (Bressoud et al., 2015). Often, students feel they do not understand the material well enough; many lack adequate mathematical confidence, and, in some cases, students lack mathematical preparation (Bressoud et al., 2015; Ellis, Fosdick, & Rasmussen, 2016; Ichinose & Bonsangue, 2016; McGivney & Fei Xue, 2013; Sonnert et al., 2015; Tootoonchi, 2016). Many university students are required to take remedial math courses before taking calculus, which often prevents them from obtaining their Bachelor’s degree within four years (Ayebo, Uukkelberg, & Assuah, 2017). Taking calculus is often more challenging for adult students who are either less prepared than traditional students or have forgotten high school algebra needed to do calculus. Therefore, they usually have a much lower graduation rate (Ayebo et al., 2017).

One of the reasons that students give for losing interest in the STEM fields is the difficulty they have with calculus (Bressoud et al., 2015; Burn & Mesa, 2015; Ellis, Kelton, & Rasmussen, 2014; PCAST, 2012; Petrillo, 2016; Schoenfeld, 2016). Calculus is “the one class that seemed to be making or breaking students in mathematics and science” (Long, 2004, p. 3). It is an important “gateway” course and is a requirement for every STEM major and is commonly
the first mathematics course taken by incoming freshmen. Moreover, calculus is a prerequisite for most subsequent future classes in mathematics as well as many classes in other STEM fields (Bressoud et al., 2015; Petrillo, 2016; Schoenfeld, 2016). Nevertheless, for so many students, this requirement is an overwhelming obstacle or a huge discouragement from the pursuit of fields that build upon the insights of mathematics (Bressoud et al., 2015; Petrillo, 2016).

It appears that productive solutions to the problem of STEM majors retention may lie in the direction of improving the teaching of calculus. Teaching calculus concepts is usually undertaken primarily through algebraic representations, but as most students soon realize, calculus is a course that requires both conceptual and abstract understanding (Bressoud et al. 2015; Petrillo, 2016). Some of the difficulties for students spring from having not thoroughly learned algebra, from a lack of honed problem-solving skills, or a lack of study skills. Besides, many students claim that they fail because of poor learning experiences in the past (Bressoud et al., 2015; Palmer, 2015; PCAST, 2012). Since “chalk-and-talk” is the instructional approach predominantly used in the teaching of calculus, “better teaching methods are needed by university faculty to make courses more inspiring, provide more help to students facing mathematical challenges, and to create an atmosphere of a community of STEM learners” (PCAST, 2012, p. i).

Many researchers claim that active learning enables a student to gain a better grasp of the material, leading to better comprehension and long term retention (Bonwell & Eison, 1991; Bressoud, 2011, 2015; Freeman et al., 2014; Prince & Felder, 2006). For students to become actively engaged in learning, the teacher must make some adjustments based on student needs and be willing to create an environment that encourages students to participate during class
Lage, Platt, & Treglia, 2000). This type of environment should be a learner-centered one where students take some responsibility for their learning and have some control over their educational experience (Doyle, 2011). Furthermore, the desire to increase understanding of mathematical concepts and to adequately prepare students for college-level mathematics establish the need for redesigning and revamping how calculus is taught. Such redesigns come in many forms: inverted classrooms, bridge programs, just-in-time instruction, course coordination, peer-assisted learning, and online homework systems. The flipped classroom as a learner-centered platform is the focus of this study. The types of activities that occur within the flipped classroom are more application-based and student-centered; they are activities involving hands-on assignments such as group projects and other open-ended solving activities (Bressoud et al., 2013).

There are few studies concerned with implementing flipped learning and integrating active learning in higher education. In particular, there is a shortage of research focused on implementing active learning in calculus courses and its concomitant effects on students’ perception and achievement. This study was geared towards exploring flipped learning as an effective way of teaching calculus. There is abundant evidence that suggests motivation, learning, and achievement are enhanced when active earning and learner-centered principles are in place (Bressoud et al., 2013; McCombs & Whisler, 1997). My purpose was to explore how students develop understanding by changing the traditional way of teaching calculus and using pedagogical techniques that are radically different from how calculus is typically taught. I aim to improve my teaching practice by facilitating learning and increasing students’ motivation to achieve success. Many researchers stated that active learning enables the student to gain a better understanding of the material, which in theory, leads to better comprehension and retention
For students to become actively engaged in learning, the teacher must make some adjustments based on their needs and create an environment that encourages students to participate during class (Lage, Platt, & Treglia, 2000). This student-centered learning environment should be one where students take responsibility for their learning and have control over their educational experience (Doyle, 2008). The flipped classroom as a student-centered platform can provide such an opportunity.

**Purpose and Research Questions**

The purpose of this action research study is to explore how learners and the instructor experience learning calculus one (Calculus I) when active learning is implemented in a face-to-face and virtual classroom. To explore this purpose, the following research questions guided the study:

1. Does active learning promote a community of mathematical inquiry in a face-to-face college calculus classroom?
2. What is the perception of the instructor, as a researcher, concerning active learning in a student-centered face-to-face college calculus course?
3. What are the experiences and perceptions of students regarding how active learning techniques like flipped learning classroom affects their learning?

The next three questions were added later on due to the exceptional circumstances (COVID-19 pandemic) forced upon everyone, educational setting included. To make this study more meaningful and substantive, the same questions were visited for virtual learning using
Zoom video technology. Therefore, the study continued to address the same questions under the new Zoom teaching and learning environment and asked:

a. Does active learning promote a community of mathematical inquiry in a virtual college calculus classroom?

b. What is the perception of the instructor, as a researcher, concerning active learning in a student-centered virtual college calculus course?

c. What are the experiences and perceptions of students regarding how active learning techniques like flipped learning classroom affects their learning in a virtual classroom?

To explain the purpose of this study, the remainder of this section sets up the rationale that is divided into three subsections. In the first section, I will explore issues in teaching and learning calculus. In the second, I will examine how active learning might enhance student learning, and considers both the dynamic learning environment and methods and techniques of active learning. In the third section, I will focus on one particular mode of active learning, namely the inverted or flipped classroom concerning teaching calculus.

**Issues in Teaching and Learning Calculus**

Since calculus is one of the required introductory courses in STEM education and it is a required course in the college careers of many students, it should be taught well so that it engages students and increases their understanding. Classroom practice should foster student engagement since students learn best when they are involved in their learning (Freeman, Eddy, McDonough & Smith, 2014).
Nevertheless, many students experience their calculus classes as uninspiring, dull, or unproductive (Bressoud, Carlson, Pearson, & Rasmussen, 2012). This course is often considered a barrier to academic successes and a significant roadblock and obstacle for first and second-year students (Bressoud, 2011; Love et al., 2014; McGivney & Fei Xue, 2013), and many students cannot achieve a passing grade.

Even though the course generally covers just a few concepts such as limits, derivatives rules and applications, the fundamental theorem of calculus, and integral applications (Burn & Mesa, 2015), “learning calculus...is difficult for students, no matter what country they live in” (Robert & Speer, 2001, p. 283). Students have difficulties in learning calculus because the nature of the course involves abstract and complex ideas (Bressoud, 2011).

**Traditional Approaches to Teaching Calculus**

Teaching mathematics in higher education has traditionally been delivered through lectures. For most students learning mathematics means developing concepts and skills through a transmission model in which knowledge is passed from the teacher or a text to the student (Bressoud, 2011). When students are not engaged, they are just a passive recipient of knowledge. After a lecture, students may practice, recite, memorize, and finally do their homework. Even though these things might be helpful to learn, they do not always promote learning outcomes desired in such abstract subjects like calculus. Freeman et al. (2014) analyzed the results of 225 research studies that comparing active learning models versus traditional lecturing. Based on this metanalysis, students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning. A solely lecture-based approach to teaching calculus does not engage students and often results in failure and makes calculus courses
a barrier for prospective STEM students by lowering their enjoyment with the discipline (Bressoud, 2011; McGivney-Burelle & Fei Xue 2013).

I have been a calculus educator for a long time. Most of my students in Calculus I are first-year students. Typically, such students, particularly adult students, are unprepared and uninterested in learning calculus. They are also weak in algebra (Bressoud, 2011), which adds more challenges to what they need to know in my calculus class. They often have negative attitudes toward calculus, and they prefer, or maybe they learned, to be passive recipients of mathematical information. They often expect to learn the materials from the textbook or me with little or no personal reflective thought. As I lecture, my students take notes. As Simms and Knowlton (2008) note, “even though students are taking notes about solving math problems, they are not developing a meaningful understanding of mathematical processes” (p. 22). In other words, their learning typically ends with the conclusion of my explanation and through a passive, decontextualized, and lecture-based teaching, which often leads them to memorize and to focus on surface learning rather than understanding the mathematical concepts. Students lack engagement in activities that require sense-making, analysis, or synthesis of ideas during class. Indeed, “teaching by telling” is a general pattern for many traditional, teacher-centered calculus classrooms in which lecturing is the predominant mode of instruction (Freeman et al., 2014).

In this light, I found myself to be often one of those traditional college instructors who, according to Prince and Felder (2006):

Introduces a topic by lecturing on general principles, then uses the principles to derive mathematical models, shows illustrative applications of the models, gives students practice
in similar derivations and applications in homework, and finally tests their ability to do the same sorts of things on exams. (p. 123)

They go on to say, “more often, no attention is paid to the question of why any of that is being done. The only motivation that students get, if any, is that the material will be important later in the curriculum or in their careers” (p. 123).

Usually, “mathematics is taught as a robotic subject...this leads students to struggle in understanding mathematics courses” (Bhagat, Chang & Chang, 2016, p. 134). Traditional instructional methods in calculus are based on teachers being presenters of information through lecture and passive learner methods instead of actively engaging the learner (Bergmann & Sams, 2012; PCAST, 2012; Seymour, 2006). In a typical lecture, the emphasis is placed on the lower level of the cognitive domain of Bloom’s Taxonomy, which is hierarchical of cognitive skills, including knowledge and comprehension with some focus on application. This framework elaborated by Bloom and his collaborators consisted of six major categories: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. In terms of Bloom’s revised taxonomy (2001), students are doing the lower levels of cognitive work (gaining knowledge and comprehension) outside of class and focusing on the higher forms of cognitive work (application, analysis, synthesis, and/or evaluation) in class, where they have the support of their peers and instructor. This model contrasts from the traditional way of teaching mathematics in which “first exposure” occurs via lecture in class, with students assimilating knowledge through homework. Still, they struggle to apply the concepts taught during the course and when it comes to taking an exam. They answer the question as if they never been in the class or heard about the topics.
The Need for Improved Teaching Methods in Teaching Calculus

It is clear that teaching and learning calculus must be substantially improved, possibly through diversification of teaching methods (PCAST, 2012) and away from traditional lecture-based teaching (Bressoud, 2011, 2015; Bhagat, Chang & Chang, 2016; Freeman et al., 2014, Young, 2015). The National Study of College Calculus set out to determine how calculus is taught and what makes it effective at promoting students’ continuation into STEM fields, among other goals (MAA, 2015). The National Calculus Study determined:

The most useful skill for success in college is the ability to learn on one’s own, to be able to think critically about what one reads or views in videos, and to use this critical analysis to build a personal, coherent, and functional mental structure for the many concepts of calculus. (Bressoud, 2015, p. 184)

Research indicates that the learning environment, including pedagogy and student experience, can affect achievement, persistence, confidence, interest, and enjoyment in mathematics and STEM education (Bhagat, Chang, & Chang, 2016; Bressoud et al., 2015; Petrillo, 2016; Rasmussen & Ellis, 2013; Seymour, 2006; Sonnert et al., 2015). Pedagogical strategies that engage students in active learning calculus may result in better outcomes, both in learning achievement and controlling students’ emotional distress (Bonwell & Eison, 1991; Bressoud, 2011, 2015; PCAST, 2012; Prince & Felder, 2006). Furthermore, such strategies of engagement may provide a solution for many of the reasons that students give for leaving STEM majors. Active learning may provide opportunities to improve students’ mathematics performance by building problem-solving abilities and critical thinking skills (Freeman et al., 2014; PCAST, 2012).
To advance student outcomes in learning calculus, PCAST (2012) suggested that teachers across the country adopt active learning and use its strategies in their pedagogy. Improving calculus instruction to include opportunities to learn through active engagement methods are rooted in the learning theory of constructivism (Petrillo, 2016). Implementing active learning opportunities in calculus class, including instructional strategies with collaboration and learner-centered instruction have shown positive results in achievement (Bergman & Sams, 2012; Crouch & Mazur, 2001; Dawkins & Mendoza Epperson, 2014; Ellis et al., 2014; Jang, 2016; Lage et al., 2000; Petrillo, 2016). It appears that such methods improve the retention of information and critical thinking skills, which results in a significant increase in STEM majors’ interest and persistence (Ellis et al., 2014; Jang, 2016; Petrillo, 2016).

As a calculus instructor, I am concerned that a contributing factor to students’ lack of success in calculus in my course might be related to the traditional teaching models that I have been using. In response to this concern, I was interested in changing my classroom into a constructivist and learner-centered environment in which I could practice active learning techniques and utilize some dynamic educational activities.

**Learner-Centered Teaching and Active Learning**

To motivate students and optimize learning, Weimer (2013) recommends using learner-centered teaching. According to her, learner-centered teaching creates an environment where instructors can build a close relationship with students and help them to grasp the development of knowledge as a process rather than a product (Doyle, 2011; Weimer, 2013). This issue may be even more important for adult students since adults engage in learning from the context of their lives (Merriam, Cafferella, & Baumgartner, 2007); hence adult educators advocate the use of learner-centered instructional strategies in developing engaging, relevant educational learning
environments (Merriam et al., 2007). Learner-centered teaching and underlying adult learning theories challenge the effectiveness of transmitting knowledge from the instructor to the learner (Brookfield, 1986; Freire, 1970, 1973; Merriam et al., 2007; Mezirow, 1991). Further, some methods can promote more effective critical thinking, problem-solving, and lifelong learning skills (Hyland, Pinto-Zipp, Olson, & Lichtman, 2010). Malcolm Knowles (1990), who coined the term and learning theory of andragogy, argues that adults are self-directed, motivated to learn, and prefer active and hands-on learning strategies, which all align with learner-centered teaching. However, as Merriam, Caffarella, and Baumgartner (2007) point out, many adult learning theorists also argue that the degree that adults are self-directed depends on the context. While not all adults are going to be very self-directed when it comes to learning calculus, most of them will be more motivated to learn it if they can see how it relates to their lives. This aligns well with the notion of learner-centered teaching since it can lead to responsible, active learners who demonstrate higher levels of achievement than those taught with traditional teaching methods (Barr & Tagg, 1995; Doyle, 2011; Weimer, 2013). Active learning can help adult learners to engage in learning from the context of life (Merriam et al., 2007). From this perspective, adult learners can draw on multiple resources, including their prior knowledge and experiences, and make learning more personally meaningful.

Active learning has been shown to improve mathematics performance by building problem-solving abilities and critical thinking skills (Freeman et al., 2014; PCAST, 2012). According to Mazur, “once you engage the students’ minds, there’s an eagerness to learn, to be right, to master” (as cited in Berrett, 2012, p. 17).
The Learner-centered Teaching Environment

In a learner-centered teaching (LCT) environment, learning is not an individual activity of acquiring abstract knowledge; instead, learning naturally occurs when a person experiences a particular situation (Merriam et al., 2007). People learn as they participate by interacting with each other in a community while performing an activity (Fenwick, 2000). Individuals interact with others through physical and/or virtual engagement while using available tools in a specific physical setting under a broader influence of the norms or culture of the society (Fenwick, 2000).

Social interaction is a critical component of learning mathematics when students become involved and motivated in a mathematical community of practice. Weimer (2013) argues that within a learner-centered environment, the focus is placed on the learning by helping the student to construct new knowledge based on such aspects as previous experiences and knowledge. She posits that learner-centered instructional environments empower the learner and transform the classroom from a teaching environment to a learning environment for both the learner and the teacher.

One aim of LCT is to accommodate as many different learning styles as might be needed in a classroom (McCombs & Miller, 2006); thus, a learner-centered environment is quite different from a traditional classroom. In this environment, students take responsibility for their learning, and they are required to take on new learning roles and responsibilities beyond merely taking notes, listening to teachers speak, and passing exams. “It is an environment that allows students to take some real control over their educational experience and encourages them to make important choices about what and how they will learn” (Doyle, 2008, p. xv). Instructors are no longer the focus of the classroom, but rather act as guides and resources for learning, and the
classroom climate is created in such a way that it is conducive to optimizing learning. Weimer (2013) found many influences on instructional practice in a learner-centered classroom: balance of power in the classroom, function of the content, and the role of the teacher, student/teacher ownership of learning, and the purpose and process of assessing the learning. She suggests that a learner-centered teacher should understand that education can be empowering as the learner develops higher-order thinking and cognitive processing.

In general, LCT focuses on the student and, in particular, on the cognitive development of the student. The teacher’s goal is to help students grasp the development of knowledge as a process rather than a product (Doyle, 2011; Weimer, 2013). In a LCT, “faculty and students are both defined as active learners engage in a cooperative effort to achieve defined outcomes” (Candela et al., 2006, p. 60). This helps students create their own conceptual or cognitive models and shifts the focus from teaching to learning. In other words, in an active learning environment, teaching techniques can be adapted to aid the cognitive and intellectual growth of students (Barr & Tagg, 1995; Chickering & Ehrman, 1990, 1996; Doyle, 2011; McCombs, 2003; Weimer, 2013)

**Active Learning Methods and Techniques**

Active learning methods and techniques can be implemented in a LCT environment where the focus is on engaging learners. Students take an active role in the learning process, which may result in increased engagement and overall course satisfaction.

Active learning is learning while doing and connecting it to experience. According to Chickering and Gamson (1987), active learning is one of the seven principles of good educational practice, which helps students talk about what they are learning, write about it, relate it to past experiences, and then apply it to their daily lives. “It is the use of knowledge rather than
knowledge itself that is affected by the nature of its consequences. Use implies performance; performance entails action” (Bruner, 1985, p. 7). As Freire (1971) explained, “Knowledge emerges only through invention and re-invention, through the restless, impatient continuing, hopeful inquiry human beings pursue in the world, with the world, and with each other” (p. 72). Active learning helps students engage in discussion and stimulate group activities. It also is a way for them to verbalize the knowledge gained and compare problem-solving approaches via collaboration. Furthermore, as participants, students contribute to the dialogue, construct a variety of solutions, and learn to explain their procedures to others (Goos, 2004; Hunter, 2010; Kennedy, 2009). Active learning allows the students to be involved in critical reflection by questioning the values and assumptions behind answers suggested by others (Kennedy, 2009).

Active learning does not mean using a single teaching method; instead, it emphasizes a variety of methods such as cooperative learning, collaborative learning, problem-based learning, among others (Prince, 2004). All of these techniques shift the role of the instructor from the primary givers of information to facilitators of student learning and/or creators of an appropriate environment for learning (Bressoud, 2011; Deslauriers et al., 2011; McGivney-Burelle & Fei Xue, 2013; Prince & Felder, 2006; Talbert, 2014; Young, 2015). Students will be actively involved and engaged in higher-order thinking tasks such as analysis, synthesis, and evaluation (Bonwell & Eison, 1991). In a LCT classroom, active learning strategies encourage students to solve problems, to answer questions, to formulate hypotheses or questions of their own, to discuss, to explain, debate, or brainstorm.

There is a broad spectrum of named approaches under the umbrella term of active learning: (a) Collaborative Learning (Bruffee, 1984); (b) Inquiry-based Learning (Bressoud, 2011); (c) Cooperative Learning (Johnson, Johnson, & Smith, 1991); (d) Problem-based Learning (Prince
& Felder, 2006); (e) Inverted or Flipped Classroom Learning (Talbert, 2014; Tien, Roth, & Kampmeier, 2001); (f) Think-Pair-Share (Deslauriers et al., 2011); (g) Peer Instruction (Mazur, 1997); (h) Inquiry Guided Learning (Freeman et al., 2014); and (i) Just-in-Time Teaching (Bressoud, 2011). All these teaching strategies promote active learning and have five common elements: 1) student involvement beyond mere listening; 2) more emphasis on the development of skills and less on the transmittal of information; 3) student involvement in higher-order thinking skills; 4) student involvement in activities, such as reading, discussing, writing; and 5) an emphasis on students’ exploration of values and attitudes (Bonwell & Eison, 1991).

In recent years, inverted learning (or the flipped classroom) has been touted as one of the best practices for implementing active learning in college mathematics classes. Many educators have used this pedagogy in their classroom and reported a number of its benefits, such as improved students’ performance, perception, and retention.

**Flipped Learning**

A flipped or inverted classroom is a pedagogical approach that is grounded in active learning whereby the teacher presents an opportunity for students to become actively engage with the material in a manner that promotes higher-order thinking and deeper understanding. Proper implementation of the flipped model may have the potential to improve mathematics achievement and conceptual understanding. In contrast to the traditional classroom experience, in a flipped classroom, “students are calculating, gesturing, arguing, helping each other, teaching each other, and most importantly learning” (Jungic et al., 2015, p. 512). The concept of a flipped class is a learner-centered, active learning environment where students are included in the process of learning and facilitating. In learner-centered teaching, a faculty member asks, “What do students need to learn? Rather than what do I want to teach?” (Candela et al., 2006, p. 60).
Students need to know how to think critically and apply what they are learning to the real world. Merriam (2008) stated that instructors can foster learning to reflect critical thinking since using critical thought is itself a developmental process in adult learning settings.

The inverted or flipped classroom allows students to be actively engaged in activities and learning with small-group instruction, peer instruction, or discussion (Bergmann & Sams, 2012; Berrett, 2012.). Also, according to Bloom’s Revised Taxonomy, it allows in-class time for problems that involve higher-level thinking. According to Talbert (2014), flipped learning inverts the focus in terms of Bloom’s taxonomy, so that the bottom parts of Bloom are reserved for student self-instruction through structured activities, and class time is focused on the upper aspects of the taxonomy.

Inverted or flipped learning is grounded in constructivism and pedagogy that has evolved into a platform for promoting critical thinking, collaboration, and social interaction with teachers and peers. It allows time for the teacher to personalize education for their students while addressing the fact that not all students come to class prepared in the same way (Bergmann & Sams, 2012). It is viewed as a solution to a combination of pedagogical problems such as disengagement, passivity regarding learning, and lower levels of retention (Abeysekera & Dawson, 2015; Bergmann & Sams, 2012). The essence of inverted instruction is to stage understanding of new material before class to free up class time for more practice and productive use of knowledge via a variety of active learning techniques (Tucker, 2012).

One of the fundamental components of the inverted or flipped classroom is that class time is reserved for the more essential aspects of learning, where teachers and students can interact about underlying concepts and applications (Abeysekera & Dawson, 2015). Bergmann and Sams (2012) describe the flipped classroom in this manner: “The one unifying characteristic of all
flipped classrooms is the desire to redirect the attention in a classroom away from the teacher and onto the learners and the learning” (Bergmann & Sams, 2012, p. 96). It provides more opportunities than simple lectures for students to work with the teacher on difficult concepts and to improve their understanding of core concepts (Tucker, 2012).

The idea of inverting a classroom is not new (Tucker, 2012). It gained popularity in 2007 when Bergmann and Sams (2012), two chemistry teachers, began posting their lectures on the internet in response to outcries that the traditional lecture format is incompatible with some learning styles and that extracurricular activities and illness, and other factors impose a significant limitation on students’ availability to come to class. To make their course more compatible with their students’ needs, they designed an inverted classroom which began providing students with a variety of source materials such as online notes, lecture videos, and PowerPoint slides. They found that by giving the lecture portion to students outside of the classroom via lecture videos, students began using class time more efficiently; they were completing all their homework assignments, labs, and other activities during each class with time to spare. As a result, they concluded that an instructional model comprised of course content delivered initially via technology at home with reinforcing coursework and skill practice conducted in the classroom was a more efficient method than the usual routine of spending class time lecturing and assigning homework to be done afterward. This not only effectively helped students who had missed a class to catch up, and maintained the course pace, but also benefited students who were present in a class by reviewing any concepts they may have missed or struggle with (Bergmann & Sams, 2012).

Since that time, inverted learning has been implemented by many instructors in broad disciplines such as computer science (Lockwood & Esselstein, 2013), software engineering

In the inverted classroom, teachers take on the role of facilitator and spend time interacting individually with students (Amstelveen, 2019; Bishop & Verleger 2013; Sams & Bergmann 2013; Talbert, 2014). The lecture is no longer the center of classroom activity; instead, the student becomes the focus of the lesson, creating student-centered learning as opposed to teacher-centered instruction (Bishop & Verleger, 2013). This re-structuring increases contact time between faculty and students as well as among students themselves, which increases students’ motivation to learn (Lage et al., 200; Amstelveen, 2019; Bishop & Verleger, 2013; Sams & Bergmann 2013; Talbert, 2014). The interactive nature of the flipped classroom supports a social constructivist framework (Bergmann & Sams, 2012) and has the potential to engage students in higher-order thinking about mathematics (Tucker, 2012).

Many educators have used the inverted classroom through active learning techniques and identified benefits to teaching with this model. Nwosis, Ferreira, Rosenberg, and Walsh (2016) flipped thirty percent of their computer science course and discovered students preferred this method and felt that it helped them succeed. Furthermore, Chen, Wang, Kinshuk, and Chen (2014) used a rigorous form of the flipped classroom and found that students were more satisfied with the course, attendance increased and made more of an effort to study. However, despite all its apparent advantages, some believe there are disadvantages to using the flipped classroom.
Critics argue that this type of instruction is not suitable for all subjects, especially introductory courses (O’Flaherty & Phillips, 2015), and is not ideal for all student-learning preferences (Herreid & Schiller, 2013).

While there is much discussion of the flipped or inverted classroom, there is little research that has been conducted on inverting a calculus classroom in higher education. This will be the focus of this action research study.

**Problem Statement**

According to a report from the President’s Council of Advisors on Science and Technology (PCAST, 2012), there is an increasing proportion of occupations requiring STEM disciplinary knowledge. To keep pace, universities should have a growing proportion of STEM graduates. However, PCAST (2012) reports that the number of students who are interested in STEM majors is decreasing each year dramatically.

One of the reasons that students give for losing interest in the STEM fields is the difficulty they have with calculus (Bressoud et al., 2015; Burn & Mesa, 2015; Ellis, Kelton, & Rasmussen, 2014; PCAST, 2012; Petrillo, 2016; Schoenfeld, 2016). Calculus is “the one class that seemed to be making or breaking students in mathematics and science” (Long, 2004, p. 3). It is an important “gateway” course and is a requirement for every STEM major and is commonly the first mathematics course taken by incoming freshmen. Moreover, calculus is a prerequisite for most subsequent future classes in mathematics as well as many classes in other STEM fields (Bressoud et al., 2015; Petrillo, 2016; Schoenfeld, 2016). Nevertheless, for so many students, this requirement is an overwhelming obstacle or a huge discouragement from the pursuit of fields that build upon the insights of mathematics (Bressoud et al., 2015; Petrillo, 2016).
It appears that productive solutions to the problem of STEM majors retention may lie in the direction of improving the teaching of calculus. Teaching calculus concepts is usually undertaken primarily through algebraic representations, but as most students soon realize, calculus is a course that requires both conceptual and abstract understanding (Bressoud et al. 2015; Petrillo, 2016). Some of the difficulties for students spring from having not thoroughly learned algebra, from a lack of honed problem-solving skills, or from a lack of study skills. Besides, many students claim that they fail because of poor learning experiences in the past (Bressoud et al., 2015; Palmer, 2015; PCAST, 2012). Since “chalk-and-talk” is the instructional approach predominantly used in the teaching of calculus, “better teaching methods are needed by university faculty to make courses more inspiring, provide more help to students facing mathematical challenges, and to create an atmosphere of a community of STEM learners” (PCAST, 2012, p. i).

Many researchers claim that active learning enables a student to gain a better grasp of the material, leading to better comprehension and long term retention (Bonwell & Eison, 1991; Bressoud, 2011, 2015; Freeman et al., 2014; Prince & Felder, 2006). For students to become actively engaged in learning, the teacher must make some adjustments based on student needs and be willing to create an environment that encourages students to participate during class (Lage, Platt, & Treglia, 2000). This type of environment should be a learner-centered one where students take some responsibility for their learning and have some control over their educational experience (Doyle, 2011). Furthermore, the desire to increase increasing student understanding of mathematical concepts and to adequately prepare students for college-level mathematics establish the need for redesigning and revamping how calculus is taught. Such redesigns come in many forms: inverted classrooms, bridge programs, just-in-time instruction, course coordination,
peer-assisted learning, and online homework systems. The inverted classroom as a learner-centered platform is the focus of this study. The types of activities that occur within the inverted classroom are more application-based and student-centered; they are activities involving hands-on assignments such as group projects and other open-ended solving activities (Bressoud et al., 2013).

There are few studies concerned with implementing inverted learning and integrating active learning in higher education. In particular, there is a shortage of research focused on implementing active learning in Calculus courses and its concomitant effects on students’ perception and achievement. This study was geared towards exploring inverted learning as an effective way of teaching calculus. There is abundant evidence that suggests motivation, learning, and achievement are enhanced when active earning and learner-centered principles are in place (Bressoud et al., 2013; McCombs & Whisler, 1997). My purpose was to explore how students develop understanding by changing the traditional way of teaching calculus and using pedagogical techniques that are radically different from how calculus is typically taught. I aim to improve my teaching practice by facilitating learning and increasing students’ motivation to achieve success. Many researchers stated that active learning enables the student to gain a better understanding of the material, which in theory, leads to better comprehension and retention (Bonwell & Eison, 1991; Bressoud, 2011, 2015; Freeman et al., 2014; Prince & Felder, 2006). For students to become actively engaged in learning, the teacher must make some adjustments based on their needs and create an environment that encourages students to participate during class (Lage, Platt, & Treglia, 2000). This student-centered learning environment should be one where students take responsibility for their learning and have control
over their educational experience (Doyle, 2008). The inverted classroom as a student-centered platform can provide such an opportunity.

**Action Research and Positionality**

This action research study will be guided by a qualitative research paradigm, which is often employed to explore the whys and hows of human behavior, opinion, and experiences (Lee, 2014). When researchers are interested in learning in-depth information about a specific phenomenon, qualitative research methodologies are employed to obtain a rich narrative from participant interviews, document analysis, and fieldwork (Merriam & Associates, 2002).

According to Merriam and Tisdell (2016), the central tenets of all qualitative research is that individuals construct their understanding of reality in interaction with their social worlds. To understand the nature of qualitative research, they identified four key characteristics: (1) the focus is on the process, understanding, and meaning; (2) the researcher is the primary instrument of data collection and analysis; (3) the approach is inductive; and (4) the product is richly descriptive (Merriam and Tisdell, 2016). Also, the primary means of data collection in qualitative research are interviews, observations, and the analysis of relevant documents.

Qualitative research was appropriate for this study because the overall purpose of qualitative research are “to understand how people make sense of their lives and their experience” (Merriam & Tisdell, 2016, p.24). This makes it the right approach to examine various aspects of adult teaching and learning, including how individuals construct knowledge (Merriam, 2000). Within the qualitative paradigm, there are many specific methods of research that can be used to highlight the socially-constructed reality of participant meaning-making. For this study, a qualitative action research approach is used. The purpose of action research is to solve a problem or to make change happen while the research process is going on (Stringer,
2014). It is a form of research conducted by practitioners with learners or other practitioners to improve practice. In this case, as a calculus instructor, my purpose is to research with my students to improve my teaching practice and to increase student learning by engaging with them in developing and participating in learning activities in a flipped or inverted classroom situation.

In speaking action research methodology, Merriam and Tisdell (2016) offer the following example, which is directly related to my project: “A teacher might begin to wonder whether or not a particular intervention will improve the math skills of her students. She might develop an intervention strategy and study effects over time, simultaneously engaging students in the process” (p.49). Action research is about changing some aspects of practice and engaging in activities that “organizational or community members have taken, are taking, or wish to take” (Herr & Anderson, 2015, p. 4) to discover potential solutions or work towards improving their practice.

Since there is a need to improve the practice of teaching calculus, action research is the most appropriate methodology to study a constructivist, flipped, or inverted learner-centered approach. My aim of creating a learner-center classroom and the use of active learning techniques fit in the purpose of the action research approach to solve a practical problem or make an improvement to practice (Stringer, 2014). The details of how I collected data through observations of activities, documents created for or in-class use including student assignments, syllabi, etc. and the steps of the action research process itself will be discussed further in chapter three.

Theoretical Framework

The theoretical framework that informs this study is constructivism, which assumes learning is an active and constructive process. Constructivism is an approach to teaching and
learning based on the premise that learning is the result of mental construction. In other words, students learn by fitting new information together with what they already know (Gordon, 2009; Powell & Kalina, 2009). Constructivism encourages students to create their understanding and knowledge of the world through experiencing things and reflecting on those experiences (Gordon, 2009). Two broad interpretations of constructivism are found in education: cognitive and social. While cognitive constructivism is concerned with how a learner creates understanding (Piaget, 1969; Powell & Kalina, 2009), social constructivism argues that learning occurs through participation in a social environment with others (Powell & Kalina, 2009). Social constructivism claims that reality is constructed, not discovered, through human activity (Martin, 1994), and knowledge is a human product (Ernest, 1999). Active learning or student-centered learning is typically part of constructivism, and these orientations that are part of constructivism will be discussed further in Chapter Two.

An additional theoretical framework, a community of mathematical inquiry, guided this study. A community of mathematical inquiry (CMI) is an environment that encourages students to develop their understanding through dialogue (Kennedy, 2009). Students are active participants in knowledge acquisition and are actively engaged in re-structuring what they already know (Goos, 2004). CMI discounts memorization as a learning tool as well as other forms of passive learning (Hunter, 2010; Kennedy, 2009). In a community of mathematical inquiry, discussions are developed through critical thinking interventions, giving examples, or counter-examples asking for justification (Kennedy, 2009). In addition, students debate a solution by offering reasons and clarifications, making propositional statements, and even exploring alternative positions and hypotheses (Kennedy, 2005,2009; Goos, 2004).
A community of mathematical inquiry (CMI) encourages students to work together in groups to solve more complicated mathematical problems (Hunter, 2010; Kennedy, 2009). Working in groups, students develop their process and then present what they have created to the class for critical review. In fact, instead of training for mastery of mathematical procedures presented by their teacher, in this process, students become apprentices (Kennedy, 2009).

**Significance of the Study**

This study aims to contribute to the fields of STEM education, adult education, and also to my personal and professional growth as an adult educator and researcher. The Unites State needs more STEM graduates, and to achieve this goal, over the next decade, universities must produce about one million more STEM graduates than predicted by current graduation rates (PCAST, 2012). For increasing STEM graduation rates, the attention must be turned towards STEM courses such as Calculus (Bressoud, 2011, 2015; Bressoud et al., 2012). Calculus is one of the introductory courses that, if taught well, can provide students with a positive and successful first-year experience and foundation for more advanced mathematics courses (Bressoud et al., 2012; PCAST, 2012). The literature shows that there is a need to investigate alternative ways of teaching calculus within the traditional classroom structure (Bressoud, 2011; McGivney & Fei Xue, 2013; Talbert, 2014). This need indicates the significance of this research study that aims to implement learner -center pedagogy and explore its effects on learning college calculus.

The results of this study also have the potential to contribute to higher education by implementing learner-centered teaching as pedagogy in adult education. The issue of teacher-centered versus learner-centered education is significant to students, teachers, and academia at large, as learner-centered teaching could be one of the answers to individualizing instruction and creating a classroom environment that increases learning and higher-order thinking. Learner-
centered teaching methods include such strategies as “inverted classrooms” where students complete the majority of content before class, which leaves class time for more hands-on and experiential learning (McGivney & Fei Xue, 2013).

The information gained from this study can help other adult educators to understand how to foster change in their practice and integrate active learning in teaching calculus. In particular, this research helps other practitioners to learn more about the community of mathematical inquiry, as a new way of understanding and rethinking about the teaching and learning of mathematics. My study may offer a promise for “the transformation of mathematics teaching and learning from a rigid, transmissive model to one which is student-centered, self-regulatory, and inquiry-driven” (Kennedy, 2009, p.76). Doyle (2011) contends that creating a learner-center environment may be the most critical thing that faculty can do to improve student learning.

This study can also be personally and professionally significant as it seems the typical lecture-based teaching is not adequate for my students, and I can no longer afford to ignore the possible ways that might improve my teaching practice. Many of my students are not satisfied with their grades, which makes them not only discouraged and far away from their career plans, but also emotionally anxious. In a passive learning environment, students memorize and repeat mathematics formula. This directly influences students’ psychological and long-term personal development (Zhang, 2005). “Subsequently, students’ interest, autonomy, creativity, and practical skills are overshadowed and diminished by traditional mathematics teaching society” (Zhong & Tu, 2013, p.18). Moving away from passive learning, this action research help me to implement learner-centered teaching and empower my students to pursue understanding based on their curiosity, insights, and intellectual strengths. Moreover, the community of mathematical
inquiry can, in parallel, equip each of my students with advanced self-learning abilities, problem-solving skills, cooperation, critical insights, creativity, and responsibility.

Assumptions, Limitations, and Strengths

There are several assumptions embedded within this study, as well as limitations and strengths that must be clarified here.

Assumptions

1. Teaching mathematics in higher education is lecture-based. This means students develop concepts and skills through a transmission model in which knowledge is passed from the teacher or a text to each student (Berry et al., 1999; Bressoud, 2011, 2015).

2. Calculus occupies a unique position as gatekeeper to the disciplines in science, technology, engineering, and mathematics (STEM). Calculus courses are barriers for prospective STEM students by lowering their confidence and their enjoyment with the discipline (McGivney-Burelle & Fei Xue 2013).

3. My class is a traditional college mathematics classroom, teacher-centered. Students learn through passive and decontextualized, lecture-based teaching, which often leads them to memorize and to focus on surface learning rather than understanding mathematical ideas.

4. Constructivism is more effective than lecture teaching, and students will prefer being active constructors of knowledge rather than being passive learners.

5. A constructivist, active classroom will create a more effective teaching and learning environment than a traditional, lecture-based teaching approach.

6. A learner-centered teaching classroom is an appropriate environment to foster active learning methods in a college calculus classroom.

7. Learner-centered teaching can motivate the students to take responsibility for their learning.
8. Through action research, I will be able to examine my practice for improvement adequately, and students will find the action research project enjoyable and meaningful.

9. This action research will take place over one semester, which constrains the topics that students should learn in calculus I.

10. The findings of this study may not be generalizable outside of this action research study.

**Limitations**

1. As an instructor, I have a position of power that may interfere with the students’ perception of free expression. In other words, students may simply respond that they think I want to hear.

2. Action research is unpredictable, and this is also the first time I am engaging in action research. The brevity of experience that I have maybe considered a limitation of the study.

3. My research won’t consider the impact of some factors, such as high school mathematics courses taken that might impede or supplementary instruction, online sources, and college success courses that promote learning calculus.

**Strengths**

Despite these limitations, there are some strengths to the study. First is my vast experience in teaching calculus, where I have a good idea of what works and what doesn’t work so well. The purpose of action research is to improve practice, and practice is best enhanced if one has a wealth of experience as a starting point.

Secondly, one of the strengths of the study is the care I will take in documenting the AR process, by analyzing my observational notes, by gathering data from participants throughout the process, and by engaging in a careful analysis.
Definition of Terms

**Action Research:** Action research is a form of practitioner research. It not only seeks to understand how participants make meaning or interpret a particular phenomenon or problem in their workplace, community, or practice, but it also usually aims to engage participants at some level in the process to solve a practical problem. (Merriam and Tisdell, 2015 p.49)

**Active learning:** Active learning is defined as an instructional approach that engages learners in their educational maturation (Prince, 2004). It is a process where the student is involved in hands-on learning in the classroom. Active learning can contribute to positive student attitudes towards self and learning, increase academic achievement, as well as motivation and attendance (Prince, 2004; Bryson & Hand, 2007).

**Calculus:** The field of mathematics that deals with differentiation and integration of functions and related concepts and applications.

**Constructivism:** Constructivism is a learning paradigm based on the idea that learners actively construct knowledge by interpreting new experiences in the context of prior knowledge and previous experiences (Merriam et al., 2007). Social interactions and personal experience are central to this theory of learning as they contribute to the construction of knowledge (Gordon, 2009).

**A community of mathematical inquiry (CMI):** A learning community where students develop their understanding through dialogue. Conversation and discussion are the channels by which students in a mathematical inquiry mutually make their meaning and making inferences. The ultimate goal of a community of inquiry is to move the group as a whole and each member in it in the direction both of enhanced cognitive/conceptual and behavioral self-organization and self-regulation. (Kennedy, 2009, p.75)
**Inverted/Flipped Classroom:** Method of instruction where students view traditional lectures over mathematical procedures and concepts outside of class before the class period in which they will be using and/or applying the information (The Flipped Learning Network, 2014).

**Learner-centered:** According to Weimer (2002), being a learner-centered means the focus of instruction is on “what the student is learning, how the student is learning, the conditions under which the student is learning, whether the student is retaining and applying the learning, and how well the current learning prepares the student for future learning” (p. xvi).

**Learner-centered teaching environment:** In a learner-centered teaching environment, students learn as they participate by interacting with each other in a community and the moment’s activity (Fenwick, 2000). Weimer (2002) argues that within a learner-centered environment, the focus is placed on the learning by helping the student to construct new learning based on such aspects as previous experiences.

**Social Constructivism:** Social constructivism emphasizes the social contexts of learning, and that knowledge is mutually built and constructed. It argues that learning occurs through participation in a social environment with other students and the teacher. (Powell & Kalina, 2009)

**STEM Education:** A curriculum based on the idea of educating students in science, technology, engineering, and mathematics.

**Synchronous learning:** Student learning of online courses takes place using electronic media such as videoconferencing, chat, or other online conferencing technology where students and faculty can discuss, ask and answer questions in real-time. The instructor and students are not in the same location or time zone and meet at a pre-scheduled time.
**Zoom:** Zoom is a cloud-based video communications app that allows us to set up virtual video and audio conferencing, webinars, live chats, screen-sharing, and other collaborative capabilities.

**Summary**

This first chapter outlined, in brief, the background of the study as well as the purpose of the research. The conceptual framework that guided my study along with the purpose statement, problem statement, and research questions were also discussed. Also, this chapter gave an overview of the study methodology and the significance of the study to the various fields it intersects. This chapter ended with a discussion of the assumptions, limitations, and strengths of the study, as well as an outline of the significant terms to this study with their definitions.
CHAPTER 2
REVIEW OF THE LITERATURE

The purpose of this action research study is to explore how learners and the instructor experience learning Calculus One (Calculus I) when active learning is implemented in a face-to-face and virtual classroom. To explore this purpose, the following research questions guided the study:

1. Does active learning promote a community of mathematical inquiry in a face-to-face college calculus classroom?
2. What is the perception of the instructor, as a researcher, concerning active learning in a student-centered face-to-face college calculus course?
3. What are the experiences and perceptions of students regarding how active learning techniques like flipped learning classroom affects their learning?

The next three questions were added later on due to the exceptional circumstances (COVID-19 pandemic) forced upon everyone, educational setting included. To make this study more meaningful and substantive, the same questions were visited for virtual learning using Zoom video technology. The study continued to address the same questions under the new Zoom teaching and learning environment and asked:

a. Does active learning promote a community of mathematical inquiry in a virtual college calculus classroom?
b. What is the perception of the instructor, as a researcher, concerning active learning in a student-centered virtual college calculus course?
c. What are the experiences and perceptions of students regarding how active learning techniques like flipped learning classroom affects their learning in a virtual classroom?

This chapter is organized into four major sections: theoretical frameworks, teaching mathematics/calculus, active learning, and flipped classrooms. The first section of this chapter explores the theoretical frameworks that inform this study. It begins with a focus on constructivism and narrows to a concentration on a community of math inquiry. The second section of the chapter reviews the current literature related to the study and emphasize gaps in the literature, thereby supporting the rationale for this study. Collectively this literature review provides a background for understanding a flipped calculus course.

**Theoretical Frameworks**

The theoretical frameworks that inform this study are constructivism and the community of mathematical inquiry (CMI) as a model of learning that encourages dialogue and discussion among students (Goos, 2004). These two perspectives view mathematics learning as a social activity. As Lerman (2001) explains, when the social practices of classroom communities are discursively constituted, “people become part of practices as practices become part of them” (p. 88). Thus, within the constructivist lens of this study, the learning and use of mathematical practices are matched by “increasing participation in communities of practice” (Lave & Wenger, 1991, p. 41). Both frameworks are discussed in the following sections, as well as concerning the flipped classroom.
Constructivism

This section reviews the literature regarding the overarching theoretical framework for the study, constructivism. The review will begin with the general definition of constructivism, followed by a discussion of social constructivism.

Constructivism posits that learners construct their own ledge from their experiences and to make sense of those experiences (Glasersfeld, 1996; Merriam et al., 2007). Based on this educational theory, students construct and reconstruct meaning as they apply their background knowledge to new material. According to Baker (2011), “constructivist theory . . . stresses that learning best takes place in a holistic sense with the parts making a unified whole in a meaningful way” (p. 246). Constructivism triggers the student’s innate curiosity about the world and how things work. “Students do not reinvent the wheel but, rather, attempt to understand how it turns and how it functions” (Bada, 2015, p. 67). They try to derive their own personal intellect and construct their own interpretation (Driscoll, 2005).

Since there is no universal definition of constructivism, some consider it a theory of learning, others as a theory of knowledge. However, some other scholars and theorists believe it as a theory of pedagogy. Additional views are the theory of science, educational theory, or an all-encompassing worldview (Driscoll, 2005; Hyslop-Margison & Strobel, 2008). However, it might be a general agreement that students construct knowledge from their perception of content based on previous personal experiences, which are varied and dependent upon each learner’s ontological assumptions (Hyslop-Margison & Strobel, 2008; Merriam et al., 2007; Patton, 2015; Piaget, 1964; Weimer, 2013).

Fosnot (1996) defined constructivism as “a theory about knowledge and learning ... it is the knowledge that is temporary, developmental, non-objective, self-constructed, and socially
and culturally influenced” (p. 3). He also described constructivism according to four principles: (1) learning depends on what individuals already know, (2) new ideas occur as individuals adapt and change their old ideas, (3) learning involves inventing ideas rather than mechanically accumulating a series of facts, (4) meaningful learning occurs through rethinking old ideas and coming to new conclusions about new ideas which conflict with our old beliefs.

The constructivist perspective allows the student to interact actively in the classroom by constructing and transforming old concepts rather than being passive learners (Golding, 2011; Hyslop-Margison & Strobel, 2008). The constructivist teaching framework challenges the traditional approach in teaching, which has also been referred to as memory-oriented or didactic transmission models by Yuen & Hau, (2006) and the banking model by Freire (1976). According to Freire, the teacher deposits knowledge into the students; the students are then expected to store this knowledge until examination time when they repeat what they just memorized.

In other words, unlike the traditional teaching that emphasizes memorization and procedural fluency, constructivist views of learning emphasize the importance of the learning process (Hyslop-Margison & Strobel, 2008). Knowledge is acquired through involvement with content rather than by imitation or repetition (Ernest, 1999). In this view, it is assumed that knowledge is physically constructed by learners who are involved in active learning and make their own representations of action (Bada, 2015). According to Weimer (2002), constructivism closely aligns with many learner-centered practices. The essence of learner-centered teaching is where students are active in creating their knowledge, which is one of the main ideas of constructivism. Through this perspective of learning, the center of instruction is the learner, and knowledge cannot only be given to learners, but they must construct their meanings and
interpretation of reality where they are engaged in thought and creating their meaning related to the topic under study (Powell & Kalina, 2009).

In such a constructivist learning environment, students feel motivated as they are engaged in discussions and problem solving while at the same time feeling supported by teachers who are guiding them towards their learning outcomes (Powell & Kalina, 2009). In this environment, students have the opportunity to personally take responsibility and exercise their initiative by controlling the classroom setting with their varied life experiences. Knowledge is seen as being created, discovered, and experienced by both the students and the teacher (Powell and Kalina, 2009).

Furthermore, constructivism encourages critical thinking and empowers learners in learning (Ernest, 2009). Powell and Kalina (2009) stated that “if they [students] think critically, they will walk away with personal meaning that was constructed on their own” (p.245). The constructivist teacher will empower students and help them construct and interpret their understanding of knowledge. One of the teachers’ prominent roles is to facilitate and encourage students’ thinking processes and guide them to understand and integrate new knowledge. They provide students the opportunities to control their learning (Liu & Mathews, 2005) and emphasize knowledge and skills that are significant to the students.

Constructivist pedagogy encourages personal understanding, with no commitment to a particular view of truth. Through this view, there is no absolute truth, and any truth is as good as another truth (Liu & Mathews, 2005). As Savery and Duffy (1996) point out, “what we understand is a function of the content, the context, the activity of the learner and, perhaps more importantly, the goals of the learner” (p. 136). According to Ernest (2002), there is no right way to teach. He is purposefully vague on specific teaching methods and learning activities and
provides a framework within which a teacher can try different ideas. We make knowledge from our perceptions, which are varied and dependent upon each learner’s personal experience (Fosnot, 1996). Since constructivism takes into account the development of the person and his or her mind, it is entirely subjective to each person. Therefore, knowledge is seen as being created, discovered, and experienced by both the students and the teacher (Ernest, 2002; Liu & Mathews, 2005).

Moreover, the constructivist aspects of truth are not generalizable as humans are always trying to figure out the truth (Liu & Mathews, 2005). For example, it is quite possible to have a realist view of objective mathematical truth, but a constructivist idea of how we come to know that truth. To know mathematics is to understand how and why one operates in specific ways and not in others, how and why the results one obtains are derived from the operations, one carries out (Ernest, 2002).

Education changed from teacher-centered to student-centered as a result of constructivism (Gholami et al., 2014). It has become the preferred theoretical framework for teachers interested in changing their teaching practices (Fardanesh, 2006). With the view of a constructivist, a teacher can empower students and help them construct and interpret their understanding of knowledge. Students will mold and shape the new information so that it fits with what they already believe and know, or they will use further information to reshape, enlarge, and deepen their current understandings. Constructivism as an educational model provides the students with more control and problem-solving skills within higher-level instruction (Hyslop-Margison & Strobel, 2008); therefore, it can be a perfect framework for an inverted classroom in which class time is used for collaborative student work, problem-solving, debate, and lab work. The basic tenets of an inverted classroom in which the students play an active role in terms of processing
learning, acquiring, and constructing new knowledge (Talbert, 2014), creates a constructivist learning environment (Herreid & Kates et al., 2015; Schiller, 2013; Strayer, 2007). In such classroom model, the teacher guides the students into reflecting, sharing, discussing, and solving problems; additionally, learners have control over the lecture with the ability to review, at home, concepts that are misunderstood, ideas which need more reinforcement, and specific concepts that are of interest to the students (Davies et al., 2013; Herreid & Schiller, 2013; Hung, 2015; Touchstone, 2015).

**Social Constructivism**

Constructivist learning is influenced by cultural and social factors (Liu & Matthews, 2005). In other words, social interaction has a vital role in the student’s ability to create his or her knowledge (Schunk, 2008). In general, “constructivism derives from a philosophical position that we as human beings have no access to objective reality, that is, a reality independent of our way of knowing it “(Martin, 1994,p.1). In particular, social constructivism argues that reality is constructed, not discovered through human activity, so that societies together invent the properties of the world (Martin, 1994).

Social constructivists agree that knowledge is constructed through socially situated conversations. They argue that human beings build their knowledge by integrating what they already know with the activities, ideas, and events with which they come into contact (Liu & Matthews, 2005; Powell & Kalina, 2009). Knowledge cannot be transmitted from one person to another-it is constructed in the human mind, either individually or in response to interaction and discussion with others. According to Epstein (2002), there are nine principles of learning in which most social constructivists subscribe. These principles can be guidelines for teaching and learning and are included: learning should be active, students have to learn how to learn,
kinesthetic learning experiences and problem-solving enhance learning, language affects learning, social activity produces meaningful learning experiences, students need contextual information, and conceptual information to learn, learning takes time, and motivation to learn is essential.

According to social constructivism, knowledge is a human product, which is socially and culturally constructed in an active manner and not something which can be discovered (Gredler, 1997; Ernest, 1999), and learning occurs through participation in a social environment with other students and the teacher (Liu & Matthews, 2005; Powell & Kalina, 2009). This approach to teaching assumes that theory and practice do not develop in blankness; rather, they are shaped by the prevailing cultural assumptions of both the teacher and the students (Martin, 1994).

In this view, teaching mathematics is a widespread and highly structured social activity, and its aims, goals, purposes, rationales, and so on, need to be related to social groups and society in general (Ernest, 1999). Powell and Kalina (2009) asserted that “teachers and students must communicate to convey information and for learning to take place” (p.247). While individuals engaged in communication, they are continually working to incorporate the ideas and make sense of them as well as convince others of their point of view. Additionally, articulation is an active process of knowledge construction because it demands that the learner think critically about the content and organize the information so it can be presented to others (Powell & Kalina, 2009).

Ernest (1991, 1999,2002) argues that social constructivism is more than just a learning theory applicable to the teaching and learning of mathematics. It, according to him, is a philosophy of mathematics. He believes the aims, goals, purposes, and rationales for teaching mathematics do not exist in a vacuum. They belong to people, whether individuals or social
groups (Ernest, 1991). Mathematical objects are just the social constructs of mathematical discourse, signified by certain symbols or notations. Ernest believes that mathematics is a set of language games, based in shared forms of life. This provides a socially situated conversation as the basis for social constructivism philosophy in mathematics. Ernest (1999) explains that the necessity of logical and mathematical truth is found in linguistic conventions, rules, and social practices that are required for participation in language games. In more detail, it may be said that social constructivism views mathematics as a social construction.

The grounds for describing mathematical knowledge as a social construction and for adopting this name are threefold: (i) The basis of mathematical knowledge is linguistic knowledge, conventions and rules, and language is a social construction, (ii) Interpersonal social processes are required to turn an individual’s subjective mathematical knowledge, after publication, into accepted objective mathematical knowledge, (iii) Objectivity itself will be understood to be social. (Ernest, 1991, p.42)

A constructivist finds meaning through interaction (Creswell, 2009). Therefore, a constructivist calculus classroom would foster an environment in which students would engage with mathematics. Social interaction is an essential component of learning mathematics because it encourages the exchange of ideas and engages students in the act of thinking critically (Powell & Kalina, 2009), and that leads to personal meaning-making. The collaboration requires students to articulate their thoughts and fine-tune their constructed understanding. Learners can be exposed to many viewpoints; the different perspectives assist in the creation of knowledge and understanding, as the various perspectives were created from the varied experiences of the individuals involved. This is the essence of learner-centered teaching, where knowledge is seen
as being created, discovered, and experienced by both the students and the teacher (McCallum et al., 2015). This changes the classroom from teacher-centered to student/learner-centered.

Green (2015) discussed the influence that social constructivism has had on the development of the converted learning as a form of learner center teaching model. Besides, the inverted learning approach incorporates the zone of the proximal development concept. Vygotsky (1978) theorized this concept as “the distance between the actual level of development . . . and the level of potential development” (p. 86). This concept is the gap between what the learners can do independently and what they can do with the guidance and assistance of an instructor. In an active mathematics classroom, students will be deliberately pushed beyond that level to their zone of proximal development as they participate in activities (Vygotsky, 1978).

Active learning is more about giving the students tasks, observing them as they perform the tasks, and giving them guidance and help (Green 2015). This requires the use of scaffolding measures, including supporting resources and assistance, to enable students to bridge the learning distance between what is known and what is unfamiliar in terms of course content (Green 2015).

Active learning and constructivist strategies encourage students to communicate optimally and collaborate to solve the problems in a social context with the teacher and their peers. Then learners become more and more involved in self-assessment; they will be able to take over the task from their teachers, complementing the other skills that have acquired (Gholami et al., 2014). A constructivist teacher can use several of Vygotsky’s teaching strategies (1978), such as scaffolding, the zone of proximal development, and cooperative learning to facilitate the social constructs that arise as students learn mathematics. The constructivist approach to teaching mathematics places emphasis on presenting students with real-life problem situations for them to
formulate their inquiry questions, explore multiple interpretations, and multiple intelligences through collaboration (Çolak, 2017). When students discuss what they have learned, they are critically thinking about the material, which allows them to construct more personal meaning to the material (Powell & Kalina, 2009).

A flipped classroom is an example of a constructivist environment where teachers promote interaction and communication and assist the students in building on previous frameworks (Schunk, 2008). It emphasizes the importance of shifting the nature of the student and teacher roles within the educational setting so that the student is seen as an active agent, involved in a series of hands-on, collaborative activities. In contrast, the teacher plays a facilitative rather than an instructive role (Green, 2015). Such an environment also supports the idea of the mathematical community of inquiry in which fellow students communicate in a group, and teachers support students and scaffold learning (Powell & Kalina, 2009). It is a model that encourages collaboration, communication, and increase engagement as a substratum for optimizing students’ learning outcomes (Green, 2015; Talbert, 2014). In an inverted mathematics classroom, students work together in a community to accomplish a common goal (Schunk, 2008). This goal can be to complete an exercise, an assignment, or an assessment. Activities of the flipped classroom are intended to be dynamic. They are designed to be collaborative where students work together, present and share constructed ideas, and receive feedback from their group and teacher. This pedagogy engages students in some activities and starts the cognitive constructivist process. Students arrive in class ready to engage in in-class activities and share their constructed ideas with others. According to Ernest (1996), the essentials of teaching for this purpose have several components, which include a discussion between and among students,
between students and their teachers, projects and investigative type problems for critical skills development, problem-solving, and creativity.

**Communities of Mathematical Inquiry (CMI)**

The constructivist vision encourages the creation of learning environments that promote individual and group inquiry in which students’ informal knowledge is recognized and utilized. In such an environment, students are supposed to work primarily in collaboration with their peers on mathematical tasks (Kennedy, 2007). A community of mathematical inquiry (CMI) is a model of this environment that encourages dialogue and discussion among students (Goos, 2004). Studies in mathematical discourse support CMI as an environment that allows talking about how mathematics learning entails communication in social contexts (Cross, 2009; Goos, 2004). From this perspective, mathematics teaching and learning are viewed as social and communicative activities that require the formation of a classroom where enact practice (Lave&Wenger, 1991).

A community of mathematical inquiry can be described as a community of practice where students learn to speak and act mathematically by participating in a mathematical discussion and solving new or unfamiliar problems (Cobb, Wood, Yackel, & McNeal, 1992; Goos et al., 1999). In this community, value is placed on “practices such as discussion and collaboration...valued in building a climate of intellectual challenge” (Goos, 2004, p. 259). One of the main objectives is that knowledge cannot be constructed through transmission or individual reflection and debate. Still, it should be through sharing ideas and synthesizing each other’s ideas, which are through distributed thinking in a dialogical context (Kennedy, 2009).

Under this framework, students “questioning, offering examples, and counter-examples, asking for justification, giving reasons, offering clarifications, making propositional statements, exploring alternative positions and hypotheses, drawing conclusions, reasoning syllogistically,
making inferences, and many others” (Kennedy, 2009, p.73). Students who are engaged in such a community take ownership and increase their responsibility in their learning and felt that explaining and justifying their ideas helped them to understand mathematics (Goos, 2004). For example, one student in Goos’ study (2004) stated that “so many times I find myself trying to explain something to other people, and you find something you’ve kind of missed yourself. . . Even if they don’t know what they’re doing, explaining it to them imprints it to your mind” (p. 272). The increase and range of activity settings offer students additional ways of participation and responsibilities (Hunter, 2010). Students feel that learning mathematics is much easier than they thought; they enjoy learning and excite to learn(Goos, 2004).

Within communities of mathematical inquiry, mathematical reasoning and the social world are connected through dialogue that engages others in deep inquiry into the meaning of things (Goos, 2004). In this community, all participants are bound together, and value is placed on “practices such as discussion and collaboration...valued in building a climate of intellectual challenge” (Goos, 2004, p. 259). This change will be evident that students feel that they relate to each other, to the classroom power and authority base, and to the discipline of mathematics itself (Cornelius & Herrenkohl, 2004).

In a CMI, the role of the teacher is challenged. A teacher is not an unquestionable authority anymore, but he/she is a facilitator who “encourages the scaffolding process without providing direct answers or authoritative perspectives” (Kennedy, 2009, p. 75). The teacher’s role is prime importance in structuring the activity settings which students are held “accountable to disciplinary standards of inquiry and to fellow students’ contributions and ideas” (Cornelius & Herrenkohl, 2004, p. 477). Students, on the other hand, see themselves as part of the learning process (Kennedy, 2009). They take responsibility “to propose and defend mathematical ideas
and conjectures and to respond thoughtfully to the mathematical arguments of their peers” (Goos, 2004, p. 259).

Argumentation is defined as the act of presenting grounds for taking a particular position or conclusion (Billig, 1996). In CMI, students argue on their different views and disagreement by which they “are able to experience mathematics as a discipline that relies on the reasoning for the validation of ideas” (Wood, 1999, p. 189). It “allows individuals to deny, criticize and justify concepts and facts, as well as find opposing views and generate a new perspective in social interaction or in self-deliberation” (Rojas-Drummond & Zapata, 2004, p. 543). Through this argument, students support their view and justify their conclusions. This is considered an essential element in sustaining the active engagement of students in inquiry (Wells, 1999) and the necessary tools to learn mathematics. As a result, students learn to take various intellectual roles. Through such means, students become comfortable enough that they can take ownership and accept responsibility for their learning (Goos, 2004).

**Teaching Mathematics and Calculus from Traditional to Active Learning Modalities**

**Mathematics and Calculus and Traditional Based Instruction**

Mathematics is not just the study of numbers. To know mathematics is to understand how and why one operates in specific ways and not in others, how and why the results one obtains are derived from the operations one carries out. It is a social activity that enables people to interpret data to make decisions, analyze, and think flexibly (Schoenfeld, 2016). Fundamental to mathematical thinking is core knowledge, problem-solving strategies, effectively using resources, having a mathematical perspective, and engaging in mathematical practice (Schoenfeld, 2016). Cornehl (2019) found that,
These facets allow practitioners to seek to understand patterns of the world and mind using the following mathematical tools: abstraction, symbolic representation, and symbolic manipulation with a goal of finding solutions and exploring ways to formulate conjectures in lieu of memorizing procedures and formulas to solve problems. (p.34)

Calculus, in particular, provides the necessary mathematical tools to study any science, technology, engineering, or mathematics (STEM) major. Calculus requires the use of mathematical tools to solve non-routine problems explaining real-world phenomena. It is a course of great importance in college education. It is required for many students, whether as a foundation for a math major or as a service course, providing them with the mathematical tools necessary to succeed in another discipline. Mainly, STEM students are required to take calculus classes as a prerequisite to advanced courses (Ayebo, Ukkelberg, & Assuah, 2017; Sadler & Sonnert, 2017). In addition, calculus has a substantial impact on students’ attitudes towards mathematics and their career aspirations. Taking a calculus course helps students to apply computational skills in a variety of real-life problem-solving situations, read and solve word problems, communicate their mathematical thinking, and collaborate with their peers to complete a task (Bressoud, Mesa, & Rasmussen, 2015; Love, Hodge, Grandgenett, & Swift, 2014).

However, while college calculus is the introduction to higher-level mathematics, and it is a necessary course, and that predict the students’ success in STEM fields (Rasmussen & Ellis, 2013; Sonnert, Sadler, Sadler, & Bressoud, 2015; PCAST, 2012; Petrillo, 2016), it is also the gatekeeper to future careers in STEM (Ayebo, Ukkelberg, & Assuah, 2017; Sadler & Sonnert, 2017, 2018). There is evidence many students are reluctant to take this course, and their experience of learning calculus is one of the main reasons they frequently leave STEM majors (Bressoud et al., 2015; Petrillo, 2016; Rasmussen & Ellis, 2013; Seymour, 2006). Difficulties
among calculus students arise because the nature of the course involves abstract and complex ideas (Petrillo, 2016). They complain about challenging topics (Bressoud, 2015) and differences in the structures or deliveries of the courses (Petrillo, 2016). Some students have no idea how to begin, and they rely on memorization, primarily for passing tests and obtaining acceptable grades to give (Ellis, Fosdick, & Rasmussen, 2016). On the other hand, college calculus instructors are frequently frustrated with their students’ lack of algebra and precalculus knowledge that is needed for success in the course (Sadler & Sonnert, 2017). Although, Rasmussen et al. (2019) proposed that, contrary to popular belief, a lack of academic preparation is not the fundamental problem with students choosing to leave STEM majors, but rather the instructional experiences students have in their first-year mathematics course.

One of the main reasons that students do not do well in calculus is that passive learning is the predominant method of pedagogy in higher education mathematics. Indeed, the higher education transmission model is a traditional method for instruction (Petrillo, 2016). This method is a common instructional method whereby teachers deliver prescribed information to students as if they are depositing in the banks (Freire, 1970).

Typically, the traditional calculus classroom does not incorporate learning strategies that foster student interaction and exploration, which results in a lack of student motivation, engagement, and preparation (Bhagat, Chang & Chang, 2016). Traditional lecture-style instructional methods focus on the transmission of information rather than actively engaging the learner (PCAST 2010, 2012; Seymour, 2006). Usually, lecture-based instruction consists of theory, rote skills, and symbolic and manipulation. The lecture is followed by examples to demonstrate the application of the idea; students take notes and complete practice problems that
they should turn in at the beginning of the following class meeting. Also, students are given frequent quizzes to show how well they understood the course material.

This form of a classroom is teacher-centered. Students passively observe while the teacher lectures. Lectures involve symbolic explanations of concepts with little or no emphasis on multiple representations of concepts (Ellis, Fosdick, & Rasmussen, 2016). In a teacher-centered mathematics college class, teachers are the authoritative experts, and students are the passive recipients of the information. They break mathematical concepts and procedures into manageable pieces that students can acquire through lectures and repeated practice (Bhagat et al., 2016). After classes, students should rehearse, recite, and memorize, and later complete homework. If students have questions, they can meet teachers at a fixed time every week in teachers’ offices for help (Bhagat et al., 2016; Ellis et al. 2016).

McGivney (2013) asserts that the problem with lecturing is that students are not given an opportunity to receive support from either peers or the instructor while engaging in higher-ordered thinking. Instead, they are required to use problem-solving skills when completing their homework without any opportunities for meaningful support (McGivney-Burelle and Xue, 2013). Bressoud surveyed students in calculus at Penn State and found that only 45% of students reported listening, paying attention, or trying to understand during calculus lectures. One student said, “the prof. gives notes and does a few examples... I usually end up behind and start doodling” (Bressoud, 1994, p 9). Surprisingly, 90% of students reported going over homework problems when they study, and only 22% of students reported looking at their lecture notes. This may indicate that students are not engaging in meaningful learning under the traditional lecture pedagogy (Bressoud, 1994), which means a significant number of students in the class are not benefiting from the lecture.
In a recent study, Sonnert et al. (2015) identified two forms of teaching that may have the most impact on students’ attitudes toward learning calculus: “good teaching” and “ambitious teaching.” Good teaching describes instructors who encourage students to learn and are available for questions and support. They create a class environment that fosters and prompts students’ participation in mastery and understanding. Beyond good teaching is ambitious teaching that is distinguished by engaging students in active learning experiences such as small-group collaborations, discussion, non-routine problem solving, and explanations of thinking. Larsen et al. (2015) analyzed the national survey data and found ambitious teaching, coupled with good teaching showed the highest correlations associated with student learning and retention in calculus.

Effective calculus instruction can transform instructional practices by facilitating students learning through active learning experiences and engagement of students in their learning (PCAST, 2012). The National Council of Teachers of Mathematics (NCTM, 2000) recommended changing traditional methods to an approach that utilizes active learning by “using a constructivist method of teaching, in which learners develop meaning based on experience and inquiry” (White-Clark et al., 2008, p. 41). Rosenthal (2015) expressed that most mathematicians agree that the best way to learn mathematics is by actively doing mathematics; by discussing it with others; and by synthesizing significant ideas. Students need to do activities where they experience calculus and are really doing it.

Active learning has been shown to improve mathematics performance by building problem-solving abilities and critical thinking skills (Freeman et al., 2014; PCAST, 2012). Active learning provides experiences for students to become aware of their errors and misconceptions, create activities, and give students the chance to gain control of the concepts, encourage student
autonomy, and help them make useful and appropriate connections (Freeman et al., 2014).

Active learning opportunities, including instructional strategies with collaboration and learner-centered instruction, have shown positive results in achievement (Bergman & Sams, 2012; Dawkins & Mendoza Epperson, 2014; Ellis et al., 2014; Petrillo, 2016). In addition, active learning and student-centered instruction support conceptual gains and improve retention rates (Larsen et al., 2015).

Research indicates that the learning environment, including pedagogy and student experience, can affect calculus achievement, persistence, confidence, interest, and enjoyment in mathematics and STEM education (Bhagat, Chang, & Chang, 2016; Bressoud et al., 2015; Petrillo, 2016; Rasmussen & Ellis, 2013; Seymour, 2006; Sonnert et al., 2015). In a learner-centered classroom, “students develop their sense of mathematics – and thus how they use mathematics – from their experiences with mathematics (largely in the classroom)” (Schoenfeld, 2016, p. 7). Learner-centered teaching gives the student an opportunity to practice communicating mathematical ideas. Learners learn mathematics by doing mathematics; they are an active part of the acquisition of their own mathematical knowledge (Bhagat et al., 2016).

Learner-centered teaching approaches like inverted learning help in creating effective learning and allows students to exchange resources, question each other’s conclusions, and defend their own ideas, which requires students to use higher-ordered thinking (Schoenfeld, 2016). A flipped classroom is a pedagogical approach that provides an opportunity for these connections to be made. Proper implementation of the flipped model has the potential to improve mathematics achievement and conceptual understanding. In contrast to the traditional classroom experience, in a flipped classroom, “students are calculating, gesturing, arguing, helping each other, teaching each other, and most importantly learning” (Jungic et al., 2015, p. 512). As
Bergmann and Sams (2012) stated, the one unifying characteristic of all flipped classrooms is the desire to redirect the attention in a classroom away from the teacher and onto the learners and the learning.

**Active Learning**

In the past decade, instructors and education researchers have been exploring new instructional methods to enhance students’ learning experience. Based on these endeavors, the active learning method has been identified as a promising alternative solution to address the concerns in various disciplines (Freeman et al., 2013; Prince, 2004). For example, Andrews, Leonard, Colgrove, and Kalinowski (2011), advocated for active learning since they believe many of the learning difficulties experienced by students in undergraduate courses can be attributed to the passive role played by them during traditional lectures. There is much support for active learning in the literature because of evidence that it leads to improving learning (Andrews et al., 2011).

**Defining Active Learning**

Active learning is generally defined as any instructional method that requires a student to take an interactive role in the classroom and be engaged rather than be passively listening to the teacher. Andrews et al. (2011) defined active learning as when “an instructor stops lecturing, and students work on a question or task designed to help them understand a concept” (p.394). It involves students’ efforts to actively construct their knowledge (Carr et al., 2015). According to Prince (2004), active learning engages the students and enables them to think about what they are learning. In addition, Armbruster et al. (2009) found that active learning is the interaction between peers and instructors, where students have opportunities to apply the content and receive immediate feedback.
McLaughlin et al. (2014) emphasized that active learning enhances students’ learning outcomes and improves their motivation and attitudes. While traditional lectures involve students with note-taking, active learning strategies can promote knowledge construction by requiring students to apply concepts rather than just exposing students to ideas. It encourages students to participate in class discussions. It can promote both individual knowledge construction and social knowledge construction (Andrews et al., 2011).

Active learning is generally characterized by a shift from a teacher-centered environment to a student-centered and constructivist environment. In this light, Freeman and his colleagues (2014) conducted a meta-analysis of 225 studies comparing “constructivist versus teacher-centered course designs” in STEM disciplines. The result showed that active learning helped students to use higher-order thinking to complete activities and participate in class discussions (Freeman et al., 2014). Active learning has been shown to affect two main factors that correlate with positive gains in student learning: (a) knowledge construction; (b) student engagement (Prince 2004). The process of active learning provides students with an opportunity to engage in thinking that is active, critical, and collaborative. This form of learning creates excitement in the classroom that engages students in doing rather than just listening. Bonwell and Eison (1991) strongly recommended incorporating active learning instructional strategies like dialog, debate, writing, and problem solving, which help students involve in higher-order thinking tasks such as analysis, synthesis, and evaluation.

Besides, many mathematicians agree that the best practical strategies for teaching mathematics in higher education are those who emphasize on learners’ active role in their learning, develop students’ critical thinking skills, and focus on testing students’ knowledge and comprehension of scientific concepts (Bressoud, & Rasmussen, 2015; Bressoud, 2015;
Deslauriers et al., 2011; Talbert, 2014). Teaching strategies that promote active learning have five common elements. These include, (a) student involvement beyond mere listening; (b) more emphasis on the development of skills and less on the transmittal of information; (c) student involvement in higher-order thinking skills; (d) student involvement in activities, such as reading, discussing, writing; and (e) an emphasis on students’ exploration of values and attitudes (Bonwell & Eison, 1991).

A meta-analysis by Richardson, Abraham, and Bond (2012) found characteristics we associate with active learning, such as conscientiousness, concentration, and an in-depth approach to learning, to have a positive impact on student achievement, whereas characteristics we consider passive, such as procrastination or surface approaches to learning to be associated with a negative effect on performance. Active learning also increases student engagement during class by assigning roles and responsibilities to students that allow them to develop a new relationship to learning. (Prince, 2004). It involves students in various active learning activities such as reading, discussing, problem-solving, the use of student response systems, peer instruction, and completing worksheets in class (Freeman et al., 2014). These provide opportunities for students to reflect on their performances in these activities (Bonwell & Eison, 1991).

Although there are different forms of active learning pedagogy in which student collaborate with their classmates on practice problems or other hands-on activities, the recent studies revealed that using inverted learning and incorporating active learning techniques in the classroom help students to reach optimum levels of learning (Talbert, 2014; Zainuddin & Halili, 2016). Researchers found that engaging students in active exercises would create a learning environment where students deepened their knowledge of the content and became critical
thinkers (Zainuddin & Halili, 2016). An inverted classroom is an example of such an environment in where students are well situated to capitalize on flexible, multi-media learning opportunities and to prepare learning under their abilities as well as learn to solve their own problems through the guidance of a teacher and friends who are more competent (Freeman et al., 2014).

Several studies have focused on the role of flipped learning in facilitating “active learning.” For example, Jensen et al. (2015) conducted a longitudinal study comparing an active non-flipped classroom with an active flipped classroom. They described participants as active learners who have a dynamic and energetic role in the learning process. They also concluded, “learning gains in either condition are most likely a result of the active-learning style of instruction rather than the order in which the instructor participated in the learning process” (Jensen et al., 2015, p. 1). Additionally, Abeysekera and Dawson (2014) identified several potential benefits of using a flipped learning model as an active learning strategy in higher education. They stated that this form of active learning encourages and develops students’ critical thinking, cultivating conscientiousness, concentration, and having overall positive impacts on student achievement. Likewise, more than 30 studies of the flipped learning model showed that flipped learning activities that activated the higher-order thinking processes listed in Bloom’s Taxonomy were considered to be more engaging and affordable by students due to their flexibility (Abeysekera & Dawson, 2014; Jensen et al., 2015; McLaughlin et al., 2013; Talbert, 2014; Zainuddin & Halili, 2016).

**Defining Learner-Centered Teaching**

Learner-centered instruction and student-centered teaching are terms that have been interchangeably used in the psychology and adult learning literature to describe a teaching
approach focused on putting the learning needs of students first through teaching strategies that intentionally seek to engage them. Learner-centered teaching (LCT) is a teaching approach that has been recommended for motivating students (McCombs & Miller, 2006). The goal is to shift the role of the instructor from disseminator of knowledge to a facilitator of learning that does not treat learners as empty vessels that need to be filled (McCombs & Miller, 2006). Weimer (2002) describes learner-centeredness as the process by which learners are empowered to have greater control over the choice of subject matter, methods used, and the pace of learning instruction that scaffolds learning, all in an environment that holds individuals responsible for their own educational advancement.

According to Doyle, 2011, “the goal of a learner-centered practice is to create learning environments that optimize students’ opportunities to pay attention and actively engage in authentic, meaningful, and useful learning” (p. 9). She believes this form of learning activates parts of our brain that are responsible for driving our feelings of motivation, reward, and behavior (Doyle, 2011). To stimulate this pathway is a primary key to successful learning and releases the chemical dopamine, which gives us a little jolt of pleasure, enticing us to repeat the behavior (Genetics Science Learning Center, as cited in Doyle, 2011).

In general, learner-centered teaching focuses on the student and, in particular, on the cognitive development of the student. The teacher’s goal is to help students grasp the development of knowledge as a process rather than a product (Doyle, 2011; Weimer, 2002, 2013). The focus of classroom activities and assignments is on the student-centered approach of inquiry itself, not on the products of inquiry (Doyle, 2011; Weimer, 2002). Students create their own conceptual or cognitive models. Content, teaching style, and methods are
adapted to aid the cognitive and intellectual growth of students (Barr & Tagg, 1995; Chickering & Ehrman, 1990, 1996; Doyle, 2011; McCombs, 2003; Weimer, 2002).

Among all these researchers, perhaps one of the most well-known works concerning learner-centered teaching practice is by Weimer (2002, 2013). She believes this form of teaching is focused on learning—what the students are doing is the central concern. In her book, she talks about the key ingredients and the assumption of learner-centered teaching such as: It is teaching that engages students in the stern, messy work of learning; it is teaching that motivates and empowers students by giving them some control over learning processes; it is teaching that encourages collaboration, acknowledging the classroom (virtual or real) as a community where everyone shares the learning agenda; it is teaching that promotes students’ reflection about what they are learning and how they are learning it; it is teaching that includes explicit learning skills instruction.

Additionally, her five fundamental changes to practice initially grew out of ideas on teaching and learning that were promoted by the academy through conferences and special issue periodicals. Weimer’s (2013) learner-centered model for teaching practices incorporates five key changes: balance of power in the classroom, function of content in the course, the role of the teacher, shared responsibility for learning, and the processes and purposes of evaluation. These key changes guide the faculty’s work to implement learner-centered teaching practices. Using the five constructs for transformation allows the teacher to be grounded in a theoretical framework of constructivism, give students a share of the power in the classroom, rethink the lecture mode as the only delivery option, engage students in the responsibility for learning, adapt content-driven courses, shift the teacher from master to guide, and provide students with multiple evaluation methods that will affect the quality and depth of learning.
Ongeri (2009) found that learner-centered teaching creates an environment where the instructor builds close relationships with students and the students are nurtured and guided. In this environment, the students reciprocate in the relationship and take on more and more responsibility for their learning. Different courses serve different levels of students, as well as additional objectives. Learning remains the goal of every class. However, how to engage students in learning and how to measure student learning are the most significant challenges within the processes of teaching (Ongeri, 2009).

The learner-centered teaching concept and the flipped classroom teaching method are effectively combined to become an essential mode for today’s teaching. The goal of learner-centered teaching is to provide an environment that is consistent with constructivist learning theories, and flipped classrooms offer this learning environment for students and teachers (Ongeri, 2009). Talbert (2014) found that a variety of learner-centered teaching methods combined with inverted learning design can improve students’ motivation in different cognitive and emotional areas. Alsardary and Blumberg (2009) developed an inverted classroom in discrete mathematics. They implemented the course based on Weimer’s five key changes for teaching practices. In this experience, the students presented the class material, took take-home examinations, and following the exam, discussed exam answers on a one–on–one with the instructors. The result indicated that the students not only learned the course content but also they learned other transdisciplinary skills such as giving feedback to other students and trusting peers and the instructor.

Learner-centered teaching approaches like inverted learning help in creating effective learning and allows students to exchange resources, question each other’s conclusions, and defend their own ideas, which requires students to use higher-ordered thinking (Schoenfeld,
A flipped classroom is a pedagogical approach that gives an opportunity for these connections to be made. Proper implementation of the flipped model has the potential to improve mathematics achievement and conceptual understanding. In contrast to the traditional classroom experience, in a flipped classroom, “students are calculating, gesturing, arguing, helping each other, teaching each other, and most importantly learning” (Jungi et al., 2015, p. 512). As Bergmann and Sams (2012) stated, the one unifying characteristic of all flipped classrooms is the desire to redirect the attention in a classroom away from the teacher and onto the learners and the learning. Using the five learner-centered constructs allows the teacher to be grounded in a theoretical framework of constructivism. It gives students a share of the power in the classroom, rethinks the lecture mode as the only delivery option, engages students in the responsibility for learning, adapts content-driven courses, shifts the teacher from master to guide, and provide students with multiple evaluation methods that will affect the quality and depth of learning (Herreid & Schiller, 2013).

**Flipped Classroom**

The flipped classroom, both the term and its use in various disciplines in higher education, can be traced back to the work of Jonathan Bergmann and Aaron Sams; two science teachers who have been practicing the flipped classroom teaching approach in their classes since 2007. Initially, they used this approach to help students who missed classes due to sports and activities to catch up with the content by watching their recorded lessons at home. Then they observed that in addition to this group of students, those who had difficulty in understanding content during class also benefited from the recorded lessons. Therefore, they decided to promote this approach to the entire class and published the first flipped classroom book based on their flipping experiences (Bergmann & Sams, 2012).
Bishop and Verleger (2013) defined the inverted/flipped classroom as “an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom” (p. 4). Flipped or inverted classroom is a pedagogical approach which transforms a classroom to an interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter. According to Talbert(2014), “the inverted classroom model is so called because it inverts or “flips” the usual classroom design where typically class time is spent on information transfer (usually through lecturing) while most higher-order tasks are done outside the classroom through homework” (p.361) and other different forms of assignments.

In addition, Jensen et al. (2015) have defined this approach as: “a learning model in which content attainment is shifted forward to outside of class, and then followed by instructor-facilitated concept application activities in class” (p. 1). In a flipped class, students first learn about the content before class through text readings, instructional videos, individual or collaborative activities, or a combination of these. Then they gather together in person and be involved in collaborative learning in class through problem-based and group-based activities (Bishop & Verleger 2013; Sams & Bergmann 2013). In other words, learners are exposed to lower-order cognitive learner concepts before class that allows more time in class to address higher-order cognitive learning (Amstelveen, 2019). Therefore, the class becomes the place to work through problems, advance concepts, and engage in collaborative learning (Jensen et al., 2015). Furthermore, the extra instructional time can shift the classroom from a passive lecture-based into an active student-centered classroom in which students do additional practice exercises, group work, discussions, or projects ( Amstelveen,2019; Bishop & Verleger 2013; Sams & Bergmann 2013).
The review of the literature revealed two main perspectives of the flipped or inverted learning approach. The first consists of the new educational approaches that promote a more active role for the learner in the educational setting. These approaches move most information-transmission teaching out of class and use class time for learning activities that are active and social (Abeysekera & Dawson, 2014). These activities are often social constructivist in nature and have been referred to in terms such as student-centered learning, active learning, project-based or problem-based learning, and collaborative learning through communities of practice, which require students to complete pre- and/or post-class activities to fully benefit from in-class work (Abeysekera & Dawson, 2014). The second form consists of the resource management trends in education, including distance learning, computer-based learning environments, hypermedia-learning environments, e-learning or online learning, and blended learning (Bergmann & Sams, 2012; Lage, Platt, & Treglia, 2000; Tucker, 2012).

According to The Flipped Learning Network (2014), “flipped learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space. The resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter” (p. 1). Bergmann and Sams (2012) stated, “the one unifying characteristic of all flipped classrooms is the desire to redirect the attention in a classroom away from the teacher and onto the learners and the learning” (p, 96). Flipped classrooms provide an opportunity for students and teachers to have more time to interact that allows students and teachers to learn from each other (Abeysekera & Dawson, 2014; Bergmann & Sams, 2012). It helps students gain critical thinking skills and increase their ability to access information via technology. Also, students have the opportunity for self-paced work and engage in their learning at higher levels.
A flipped classroom is a comprehensive approach to teaching that involves instructional videos firmly integrated with purposeful classroom activities that involve active learning techniques. The use of hands-on activities in flipped classrooms allows interaction between students to discuss, formulate, and work on course content (Maciejewski, 2016).

Some mathematics instructors have suggested that the flipped (or inverted) classroom approach has the potential to improve mathematics instruction (Ford, 2015; Ichinose & Clinkenbeard, 2016; McBride, 2015). The flipped classroom allows the teacher to develop hands-on activities addressing specific content that students are struggling with or concepts that are necessary for achieving particular outcomes. Tucker (2012) argued that hands-on activities not only allow instructors to see where students are struggling but also stimulate students and encourage engagement with course content, requiring them to do something with course content rather than merely memorizing it. Tucker (2012) recommended various activities for student engagement, such as working on the blackboard, concept mapping, and role-playing, debating, and playing games. Other examples of hands-on activities are writing in journals, speed challenges, and puzzles (Ichinose & Clinkenbeard, 2016; McBride, 2015).

Flipped learning leaders distinguish between a “Flipped Classroom” and “Flipped Learning.” These terms are not interchangeable. Flipping a class can, but does not necessarily, lead to flipped learning. Many teachers may already flip their classes by having students read text outside of class, watch supplemental videos, or solve additional problems. Still, to engage in flipped learning, teachers must incorporate the learner-centered characteristics into their practice (Talbert, 2014).
The design of an inverted classroom can vary widely depending on discipline, institution, course, and even instructor. According to Bergmann and Sams (2012), “the one unifying characteristic of all flipped classrooms is the desire to redirect the attention in a classroom away from the teacher and onto the learners and the learning” (p, 96). The flipped classroom should incorporate more active learning strategies (Lage et al., 2000) and become an active learning environment (Bergmann & Sams, 2012). It also should change the interaction between teachers and students by changing the role of the teacher to a facilitator and increasing the valuable contact time between the students and the instructor. Furthermore, it has a flexible environment, which means it allows for flexible time and space for students’ interaction and reflection on their learning as needed and provides different ways for students to learn content and demonstrate their mastery. It also allows educators to conduct formative assessments and provide instant feedback to students during their learning process (Talbert, 2014).

Additionally, the design of the flipped classroom aims to push the lower cognitive-level content of Bloom’s Taxonomy, such as remembering, understanding, and sometimes applying to pre-class, so students could be able to learn on their own. Students can then focus on the higher cognitive-level skills such as analyzing, evaluating, and creating in class with the assistance of instructors and peers (Talbert, 2015). Instructors intentionally rearrange course materials to utilize the time in the flipped classroom better. They prioritize lower-level cognitive knowledge before class for students’ direct instruction and maximize class time to practice active learning strategies to deepen students’ understanding of content and improve their higher-level cognitive skills. Indeed, the flipped classroom is a constructivist environment in which students play an active role in terms of processing learning, acquiring, and constructing new knowledge (Bergmann & Sams, 2012; Talbert, 2015). This model of teaching and learning supports a social
constructivist framework since much of the class time is devoted to students working collaboratively in a group to complete the required in-class assignments (Tucker, 2012). It is stated that the flipped classroom is more efficient than the traditional classroom as valuable class time is not devoted to students attempting to follow the lecture, transfer notes from the board to their notebook, and apply the newly presented information (Bergmann & Sams, 2012).

Significantly, the flexible characteristic of the flipped classroom creates a student-centered learning environment in which students must recognize and demonstrate self-regulated learning skills to succeed in a flipped class (Talbert, 2014). Every minute of class is utilized for the students to engage in active learning. Instructors can create a more accurate representation of what students do and do not know and where potential misunderstandings may be occurring due to the increased opportunity to communicate with all students in the class, not just those that choose to participate. Instructors who have flipped their classrooms have integrated and utilized a variety of in-class activities to enable students to use and apply information learned in the video lectures (Bergmann & Sams, 2012; Talbert, 2014).

As a unique instructional model, the flipped classroom has its distinct characteristics. Flipped Learning Network (2014) describes the attributes by proposing “four pillars” that teachers must incorporate in practice to design a successful and effective flipped class. First, a flexible environment means that the flipped classroom allows for flexible time and space for students’ interaction and reflection on their learning as needed and provides different ways for students to learn content and demonstrate their mastery. It also allows educators to conduct formative assessments and provide instant feedback to students during their learning process. Second, the flipped classroom model creates a student-centered learning culture in which students take control of their learning process and are actively involved in knowledge
construction as they engage in personally meaningful activities. In other words, a flipped classroom focuses on student-centered learning, which creates rich learning opportunities to involve students in active knowledge construction and personal learning evaluation inside and outside of a flipped class. By creating a flexible student-centered learning environment, students become the owners of their learning. Third, the flipped classroom is prominent for its re-allocation of learning time and task, as well as its change of roles for teachers and students.

Teachers in a flipped class determine which materials students should explore on their own and the concepts where they might need guidance or collaborative work. Then they intentionally design the flipped course accordingly. Last, the flipped classroom places higher demands on professional educators because the in-class active learning activities require teachers to continuously observe students, assessing their performances, and providing in-time personalized feedback to help students engage in flipped learning. Since instructors do less lecturing during class, a significant amount of class time is freed up for different roles for both students and teachers (Bergmann & Sams, 2012; Talbert, 2014; Tucker, 2012).

Comparative Findings of Studies

Besides the definition, history, and characteristics, the synthesized review of the literature revealed three significant categories of flipped classroom research studies: comparative studies on achievements, teacher perspectives, and students’ perception.

Comparative Studies on Achievements

The comparative studies are the research studies that compare the traditional classrooms to flipped classrooms. Several studies have focused on the role of flipped learning in facilitating “active learning.” For example, while Abeysekera and Dawson (2014) identified some potentially negative impacts of flipped learning which they argued need to be addressed, such as
procrastination or the use of surface-level approaches to learning, they also identified several potential benefits of using a flipped learning model as an active learning strategy in higher education. These included overcoming the learning difficulties that many undergraduate students face when arriving at universities; cultivating conscientiousness, concentration, and an in-depth approach to learning; and having overall positive impacts on student achievement.

Albert and Beatty (2014) used a quasi-experimental study in a management course at San Francisco State University to compare the grades of 321 students who learned in an inverted classroom in fall 2013 with the grades of 596 students who learned the same course the traditional way in fall 2012. The researchers analyzed data using a t-test and found a significant difference between the exam grades of students in the fall of 2012 and the exam grades of students in fall 2013. Before this, Talley and Scherer (2013) also conducted an empirical study to compare the effectiveness of a flipped class to a traditional class. They integrated the flipped classroom format along with learning techniques, self-explanation, and practice testing into an undergraduate psychology course. They assessed the effectiveness of the class format by testing students’ knowledge retention at the end of the semester. The results showed that the flipped format, along with other learning techniques, increased students’ study time and led to higher exam grades.

Furthermore, Seyedmonir et al. (2014) inverted a principle of biology course at a historically African-American university. They compared the flipped class to a previous semester of the same class that was traditionally taught. They described an effective learning environment for the inverted classroom model and the way the inverted classroom can establish a thriving community of inquiry. They also discovered that students in the flipped class did better in real-world application type questions. Later in 2014, Mattis similarly employed a flipped classroom
structure for second-year nursing students in preparation for a mathematical competency exam. She found that the flipped class was more accurate on their posttest than the traditional class. Mattis also found that the flipped class was more effective with moderately to highly complex problems.

Velegol et al. (2015) likewise compared an inverted classroom to a traditional class for a large engineering course. They taught traditionally for half of the semester while the other half was conducted using a flipped classroom. The researchers concluded that students who learned in the inverted classroom had better achievement in comparison to the achievement of students of the preceding year who learned in a traditional classroom.

More recently, a study conducted by Betihavas et al. (2018) is also relevant to understanding the role of flipped learning in higher education. These authors observed that “students are well situated to capitalize on flexible, multi-media learning opportunities and to prepare learning under their abilities as well as learn to solve their problems through the guidance of a teacher and friends who are more competent” (p. 16).

Overmyer (2015) compared student achievement by grades on a common final exam in flipped (n = 136) and traditional lecture (n = 165) college algebra classes. This study showed that students in classes where the instructor uses inverted course design with other active learning high impact practices did outperform their traditional counterparts (Overmyer, 2015). However, a similar study reported little difference between their flipped and traditional sections. In 2016 Ziegelmeier and Topaz flipped an entire introductory statistics course. They compared this course with a traditional lecture course. This mixed-methods study used field notes, interviews, and focus groups to consider student perceptions of both courses. Students in the flipped course generally felt less satisfied with the structure of the course. Yet, they were more amenable to
cooperative learning and innovative teaching methods than their counterparts in the traditional course.

In addition, Schroeder and McGivney-Burelle & Fei Xue (2015) compared a flipped section to a traditional section in Calculus I. Analysis of student performance across three course exams, and a final showed that students in the flipped course saw more gains on the common final exam. A follow-up examination of Calculus II grades revealed a statistically significant difference in course grades between these two groups of students. (Schroeder, McGivney-Burelle, & Xue, 2015). This again underscores the importance of active learning and a high level of student engagement to improve student outcomes.

Likewise, Sahin et al. (2013) reported significantly higher quiz scores in their flipped Calculus classes in comparison with their non-flipped classes. However, incorporating active learning into classrooms has shown positive gains in terms of both student performance and perceptions. Another mathematics study that compared an inverted classroom with a traditional one was McGivney-Burelle and Xue (2013). They compared the exam performances in two sections of Calculus II. For the first five weeks of the course, both sections, A and B, were not flipped, whereas for the second 5 weeks of the course, group B experienced the flipping pedagogy. Both groups were tested at the end of each 5-week unit. In contrast, section A performed about the same on the two exams, the average test score of section B improved by five points (out of 100) on the second exam.

Later, Clark (2015) measured student engagement and performance in two algebra I course at a rural high school. He found that students scored similarly on unit tests when comparing the flipped class to the traditional class. Clark noted that performance measures between the flipped classroom and traditional classes were insignificant. Similarly, Strayer, 2012 conducted a mixed-
method study in Introduction to Statistics at Midwestern Christian Liberal Arts University. The purpose of this study was to compare the learning environment and the learning activities in an inverted classroom and a traditional classroom. The results showed that students were not much satisfied with the way the format of the classroom guided their learning in the course (Strayer, 2012). Results indicated that students appreciated collaboration and innovative teaching strategies in the inverted classroom. Still, they were not motivated by the way the environment guided them toward learning the course material. However, the author explained that these results could not be generalized as students were not randomly assigned, and there were some limitations to the study.

Finally, Talbert (2014) compared a flipped section to a traditional section, but this time in a linear algebra course. Analysis of student performance across three-course exams and a final showed that students in the flipped course saw more gains on the last two exams as they became more accustomed to the flipped classroom environment but performed similarly to the students in the traditional course on the final exam. Analysis of an end-of-term survey revealed that the majority of students had a positive attitude about the flipped course. The survey also showed a higher comfort level of talking with peers amongst students in the flipped classroom as compared with the traditional one. This may contribute to developing a social network, as well as to a higher perception that linear algebra is essential to their careers.

**Teachers' Perspectives**

Inverted learning consists of a set of pedagogical methods that: (a) move most information-transmission teaching out of class; (b) use class time for learning activities that are active and social; (c) require students to complete pre- and/or post-class activities to fully benefit from in-class work (p. 3). Allery (2004) found that real learning stems from the educational
experiences of students with various activities using knowledge being taught. Therefore, according to Talbert (2014), educators must explore different educational backgrounds and styles of teaching that promote students’ ability to learn.

Based upon the literature review, teachers in both secondary and higher education are using different forms of active learning for a variety of pedagogical reasons such as introducing students to more rigorous content, promoting discourse and collaboration, and to encouraging more individual responsibility for learning (Maciejewski, 2016). Besides, in some studies, inverted learning has been used to address practical problems such as lack of attendance and motivation (Little, 2015; Maciejewski, 2016). In particular, educators are interested to know whether the inverted classroom can improve students’ achievement, engagement, and attitude (Olakanmi, 2017; Petrillo, 2016; Schoenfeld, 2016).

In many studies, instructors found that inverted learning has the potential to improve learning in the classroom significantly. These include increased student performance and reduced failure rates, higher levels of peer interaction, and improvements in students’ attitudes toward learning. These authors also listed some benefits of the inverted (or flipped) classroom: (1) opportunity for students to learn according to their needs and abilities; (2) better interaction between the teacher and the students; (3) improved learning; (4) effective use of classroom time; (5) improvement in student academic performance, motivation, and engagement; (6) the strategy of the inverted classroom advocates the learner-centered classroom; and (7) the technology used in the inverted classroom is accessible and advanced; (8) enhanced learning that focuses on real life activities; (9) additional time to spend on practical work; (10) learners who did not attend class can view the lectures at their own free time; (11) the learning method encourages critical thinking; (12) better engagement in the classroom; and (13) students actually enjoy the inverted

Some studies indicated that instructors like inverted teaching since they can interact with their students, which in turn increased motivation to learn the subject (Davies et al., 2013; Freeman et al., 2014; Herreid & Schiller, 2013; Olakanmi, 2017; Petrillo, 2016; Schoenfeld, 2016). Advocates for a flipped classroom claimed that their role in the flipped classroom changes from “sage on the stage” to the “guide on the side,” which means the responsibility in the inverted classroom moves from instructors to students (Davies et al., 2013; Freeman et al., 2014; Herreid & Schiller, 2013). This model improves student motivation, engages students, and improves relationships in the classroom as compared to traditional classrooms (Davies et al., 2013; Freeman et al., 2014; Herreid & Schiller, 2013; Tucker, 2012). In addition, some educators agreed that the flipped classroom approach creates a student-centered learning environment in which students take control of their learning process by being held accountable for the preparation before class and the engagement during class (Bergmann & Sams, 2012; Lage et al., 2000; Moran & Milsom, 2015; Tucker, 2012). This approach was found to facilitate a cooperative learning environment, and it encouraged the students to become active participants in the learning process (Strayer, 2012).

However, while many of the benefits have also been documented in flipped classroom studies, some educators warn that flipping should be approached with caution (Jensen, Kummer, & M Godoy, 2015; Strayer, 2012; Zack, Fuselier, Graham-Squire, Lamb, & O’Hara, 2015; Moran & Milsom, 2015). These educators identified some concerns and difficulties. They stated that getting students to prepare for class can be a challenge with any pedagogy, but underprepared students present a particular challenge in the flipped classroom since this teaching
model relies heavily on student participation (Lamb et al., 2015; Moran & Milsom, 2015). Finally, while many students enjoy the additional freedom of the flipped classroom, some naturally resist any departure from the traditional course format (Lamb et al., 2015).

As a result, this model may become a hindrance to learning, leading students to experience negative views toward technology and lower opinions of the course and instructor (Berrett, 2012; Zack et al., 2015). Also, flipping can be very labor-intensive for instructors since it takes time to prepare or create course materials such as videos, tutorials, or self-assessment tests (Talbert, 2014). According to Jungić et al. every (2015), “30 minutes of video content equates to roughly 3-4 hours of recording, editing, and uploading” (p. 3). Furthermore, teachers and instructors mainly complained about facilitating group work and student collaboration (Berrett, 2012; Lamb, & O’Hara, 2015; Moran & Milsom, 2015). Sometimes students forget to watch the videos before attending class, and consequently, they cannot engage in the learning process (McGivney-Burelle & Xue, 2013). Moreover, students who did watch the videos were dissatisfied that they were unable to ask the instructor questions as they arose (McGivney-Burelle & Xue, 2013). Studies regularly report that flipped classrooms can be met with resistance from students accustomed to more traditional methods of instruction (Lamb, & O’Hara, 2015).

In particular, some educators stated that flipping might not be an ideal teaching model for first-year students. The transition from high school to university requires many adjustments already, and hence a radically different teaching style may be overwhelming to first-years students. This is supported by the fact that the greatest disapproval for the flipped model occurred in the precalculus course, the only one of the four in which first-year students comprised 100% of the class (Schoenfeld, 2016). Furthermore, students in lower-level courses
may be more resistant to taking ownership of their learning and consequently may neglect to watch the videos before attending the class (Schoenfeld, 2016).

**Students’ Perceptions**

Besides the comparative study category, the other major category that emerged from the flipped classroom literature review was student perceptions. These studies did not compare flipped classrooms with the traditional classroom; instead, they were focused on examining students’ attitudes towards the class format and their engagement in a flipped class. The result of these studies indicated mixed results about the students’ beliefs and attitudes toward flipped learning. However, the majority of them found that students, on average, held positive attitudes towards the flipped classroom and engaged more in course learning (Bishop & Verleger, 2013; Chen, Wang, & Chen, 2014; Davies et al., 2013; Lage et al., 2000; McCallum et al., 2015; McGivney-Burell & Xue, 2013; Petrillo, 2016; Touchton, 2015).

For example, in 2010, Papadopoulos and his colleague conducted a study at the University of Puerto Rico to compare the inverted model to the traditional lecture-style classroom. The researchers assessed students’ reactions to the inverted classroom through a detailed student survey, and results indicated that students prefer the inverted model compared to the traditional lecture-style courses. Also, a meta-analysis identified common results from 24 studies taking place between 2000 and 2012. Based on this report, students liked the interactive class time more than in-person lectures (Bishop & Verleger, 2013). Then Butt (2014) presented a report on an introduction of a flipped lecture in a final-year actuarial course. He flipped the large lecture actuarial course by moving the “delivery” of material outside of formal class time and using formal class time to help students undertake collaborative and active activities relevant to the materials. By conducting survey research at the start and end of the semester, he found that
students, on average, became more positive towards the flipped approach after experiencing the entire course. His study suggests that a flipped approach could be perceived as a positive approach for a large lecture course.

In a study by Lage et al. (2000), students expressed positive learning experiences towards this form of active learning. They noted that they felt more comfortable seeking the instructor out for assistance and feedback in the flipped classroom (Lage et al., 2000). One student said, “I liked the demonstrations and the group work – they helped me to see the concepts, much better than a lecture would, and I could better visualize something I’d seen rather than heard – that was a big plus for tests” (Lage et al., 2000, p. 35). Other studies that showed the students’ preference for inverted learning was led by Davies and his colleagues (2013). The researchers directed weekly online surveys to analyze students’ perceptions of the inverted classroom. Around 80% of students agreed that the inverted classroom approach improved their self-efficacy for learning when studying for the final examination. Many of them would like to see more teachers implement the inverted classroom approach. One student commented,

As for the class itself, I loved the way it was run! The groups were very effective – it helped to have your peers explain things to you in a different way that sometimes made more sense. Also, it was easier to get to know your classmates and made for a very comfortable environment. I liked the ‘hands-on’ approach. (Lage et al., 2000, p. 35)

Also, Love et al. (2015) found that nearly three out of four students in a Linear Algebra course stated that they would prefer to continue learning in an inverted, and they believed the use of collaborative learning within the course helped them better remember the content. However, not every student prefers instructional practice. The most common complaint typically relates to the requirement of preparation for each class, which often is watching lecture videos and taking
notes. Similarly, results from a mixed study conducted in an English course at a Taiwanese university indicated significant students’ satisfaction. More than 80% of participants from the inverted classroom stated that they were more motivated to spend time and hard work on an inverted designed course than on a traditionally designed one. A student commented,

I really enjoyed the class setup and structure. I was a little nervous after the first day of class when we talked about how much responsibility is required for this class, but it wasn’t as bad as I thought. I really enjoyed the labs and worksheets that we do in class because it really helped me understand the chapters. It also really helped as a study guide for exams. I also like the way the class is sort of informal because it makes me feel more comfortable asking questions. (Lage et al., 2000, p. 35-36)

In addition, Schroeder and McGivney-Burelle & Fei Xue (2015) lead a mixed-methods study to examine students’ perceptions of the flipping pedagogy. Students in the flipped courses reported spending, on average, an additional 1–2 hours per week outside of class on course content. Students enrolled in the flipped sections also performed better than students from the non-flipped sections on the common final exam. A follow-up examination of Calculus II grades revealed a statistically significant difference in course grades between these two groups of students. The findings from this exploratory study are encouraging. Students enrolled in flipped sections of calculus I spent more time outside of class working on mathematics and spent more class time working on, discussing, and presenting solutions to problems. In addition, students enrolled in the flipped sections performed significantly better than their peers on the common final exam. Furthermore, the follow-up analysis of calculus II grades suggested that the benefits from enrolling in a flipped calculus I course may extend into performance in calculus II.
In contrast to the positive findings, some studies, however, found students were not satisfied with their learning experiences in the flipped class and disliked how the classroom structure oriented them to the learning tasks (Strayer, 2012). Results showed that students appreciated collaboration and the innovative teaching strategies in the inverted classroom, but they were not motivated by the way the environment guided them toward learning the course material. Students noted that the flipped classroom requires a lot of responsibility on their part and increases their workload (Seyedmonir et al., 2014). Consequently, they may come unprepared for in-class learning activities, which can result in low performance in these classes (Herreid & Schiller, 2013). For the students who have already experienced flipped classrooms, they might still feel frustrated when exposed to a significant amount of content knowledge before class and feel confused when they find disconnections between pre-class materials and in-class activities. In this light, Jaster (2013) conducted a mixed-method study on an inverted college algebra class, in which students viewed videos and took notes outside class and solved problems in class. Results revealed that students’ perceptions of the inverted classroom were varied, and grades’ comparison showed that there was no significant difference between students’ achievement in the three classes. One of his major findings was that the majority of students preferred a lecture-based class over the inverted class. The qualitative analysis of students’ feedback indicated that students felt more work was required in the inverted class. That pre-class watching videos or taking notes was very time-consuming. Likewise, Schullery et al. (2011) conducted a study about an inverted classroom with 868 participants. The quantitative and qualitative analysis showed that the majority of students were strongly positive towards the inverted classroom while a few students were extremely negative. Data in that study
demonstrated that 64% of the students felt that it was just as easy to take notes from an online lecture as it is during a traditional lecture.
CHAPTER 3

METHODOLOGY

According to a report from the President’s Council of Advisors on Science and Technology (PCAST, 2012), there is an increasing proportion of occupations requiring STEM disciplinary knowledge. To keep pace, universities should have a growing proportion of STEM graduates. However, PCAST (2012) reports that the number of students who are interested in STEM majors is decreasing each year dramatically. One of the reasons that students give for losing interest in the STEM fields is the difficulty they have with calculus (Bressoud et al., 2015; Burn & Mesa, 2015; Ellis, Kelton, & Rasmussen, 2014; PCAST, 2012; Petrillo, 2016; Schoenfeld, 2016).

The purpose of this action research study is to explore how learners and the instructor experience learning Calculus One (Calculus I) when active learning is implemented in a face-to-face and virtual classroom. To explore this purpose, the following research questions guided the study:

1. Does active learning promote a community of mathematical inquiry in a face-to-face college calculus classroom?
2. What is the perception of the instructor, as a researcher, concerning active learning in a student-centered face-to-face college calculus course?
3. What are the experiences and perceptions of students regarding how active learning techniques like flipped learning classroom affects their learning?

The next three questions were added later on due to the exceptional circumstances (COVID-19 pandemic) forced upon everyone, educational setting included. To make this study more meaningful and substantive, the same questions were visited for virtual learning using
Zoom video technology. The study continued to address the same questions under the new Zoom teaching and learning environment and asked:

a. Does active learning promote a community of mathematical inquiry in a virtual college calculus classroom?

b. What is the perception of the instructor, as a researcher, concerning active learning in a student-centered virtual college calculus course?

c. What are the experiences and perceptions of students regarding how active learning techniques like flipped learning classroom affects their learning in a virtual classroom?

Conducting a qualitative action research design in a particular classroom was best approached for the purpose of this study and its research questions. Critics of qualitative studies have called these investigations “unscientific, or only exploratory, or entirely personal and full of bias” (Denzin & Lincoln, 1998, p. 7). However, the purpose of action research is to make change happen and observe how it unfolds in the process as well as to present the final findings of the study. Further, qualitative research methodologies are especially appropriate to use when there is little known about a specific phenomenon (Merriam & Simpson, 2000). This makes it suitable for this research study since there is just a little known about the impact of active learning on learning such an abstract subject like calculus.

Given that this is a qualitative action research study, this chapter begins a brief overview of qualitative research in general, followed by a detailed description of the research methodology, action research. This chapter will also include a discussion of my background as the researcher followed by criteria for participant selection, data collection, and data analysis processes. It will conclude with a discussion regarding the trustworthiness of the study.
Qualitative Research Paradigm

A qualitative research paradigm guided this action research study. Qualitative and action research methodologies are often used in the field of adult education to understand aspects of adult learning to find out how adults perceive or understand their world (Merriam & Simpson, 2000). According to Creswell (2013), “qualitative research begins with assumptions and the use of interpretive/theoretical frameworks that inform the study of research problems addressing the meaning individuals or groups ascribe to a social or human problem” (p. 44). Qualitative research is concerned with how individuals “interpret their experiences, how they construct their worlds, and what meaning they attribute to their experiences” (Merriam, 2009, p. 5). This perspective focuses on understanding the nature of a problem or issue and offers a deep understanding of a particular phenomenon (Merriam, 2009; Patton, 2015).

Learning mathematics is sometimes imagined by students to be a dry, overly academic domain, and never related to individuals. However, the aims, goals, purposes, and rationales for teaching and learning mathematics do not exist in a vacuum. They belong to people, whether individuals or social groups (Ernest 1991). For example, when the COVID-19 pandemic has spread, math has had a daily effect on people’s lives—even they didn’t have to crunch the numbers themselves. Mathematics was used to figure out how much social distancing was required to flatten the curve. The hospitals used mathematics to estimate the number of beds or ventilators that they needed. Many mathematicians created Mathematical modeling to predict illness or death, which all led to effective control measures. The researchers realized that they could apply basic calculus to that process when considering disease spread and come up with a set of differential equations to study the rate of change of the number of people susceptible to the disease in a given population. Similarly, modeling was used to quickly identify which countries
were most at risk of experiencing imported cases. In fact, the idea of using mathematics in
disease spread or other world problems is not new; however, today, the COVID-19 crises have
highlighted the values of science and STEM education more than ever.

A wealth of research literature exists on how mathematics opens opportunities for
students and helps them to pursue STEM education. But it lacks on how instructors can facilitate
rich, meaningful learning experiences and improve teaching and learning college calculus
classroom. To ease my student success, this study intended to explore implementing active
learning. In this light, to examine how active learning is perceived, applied, and experienced in
a particular higher education classroom, the qualitative study was a relevant inquiry. Merriam
(1998) states that “qualitative research focuses on process, meaning, and understanding” (p. 8). It
“uncover the meaning of a phenomenon for those involved” (Merriam & Simpson, 1995,
p.97), and it enables the study to look for participant and researcher perspectives on the process
of learning.

Qualitative research is interpretive. It is “the socially constructed nature of reality, the
intimate relationship between the researcher and what is studied, and the situational constraints
that shape inquiry” (Denzin & Lincoln, 2008, p. 14). In my study on active learning,
understanding the nature of the experience emerged from observing students engaged in different
activities. I was the facilitator and also the primary instrument of data collection and analysis.

Merriam (2009) states that researchers conducting qualitative research are interested in
understanding “(1) how people interpret their experiences, (2) how they construct their worlds,
and (3) what meaning they attribute to their experiences” (p. 23). According to Merriam and
Tisdell (2016), the central characteristics of all qualitative research is that individuals construct
reality in interaction with their social worlds. To understand the nature of qualitative research,
they identified four key characteristics: (1) the focus is on the process, understanding, and meaning; (2) the researcher is the primary instrument of data collection and analysis; (3) the process is inductive; and (4) and the product is richly descriptive.

Qualitative research has other characteristics that make it productive for this research study. Since qualitative research aims to examine a phenomenon in-depth and to find out from participants how they make meaning of their experience, it can be used to gain insight into people’s attitudes, behaviors, value systems, concerns, and motivations (Patton, 2015). Also, qualitative researchers utilize various interconnected approaches and typically engage in multiple means of data collection such as interviews, observations, and documents (Merriam & Tisdell, 2016), that seeks to get at a better understanding of the subject matter. In addition to my experience as a calculus educator that provides an intimate perspective when studying the inverted classroom, using qualitative inquiry gives me the chance to provide rich details and insights on the participant’s experience (Lincoln & Guba, 1985). Patton (2015) stated that thick description’ provides the foundation for qualitative analysis and reporting. Thick description takes the reader into the setting being described in such a way that he/she can understand the phenomenon studied and draw his or her own interpretations of meaning and significance (Patton, 2015).

I chose qualitative because I wanted to understand the active learning within the context of a calculus classroom. My study was conducted in the natural setting (classroom) that provided numerous opportunities to listen to and engage in conversational-dialogue and to collect and analyze descriptions and reflections from the participants. In addition, action research was the best fit since this research was dynamic and had the potential to change the needs of both my student participants and my practice. I used a qualitative action research study. This paradigm
allowed me to thoroughly understand the perceptions of myself (researcher) and my students (participants) concerning the learner-centered environment and active learning and their impact on learning calculus. The qualitative action research paradigm allowed me to thoroughly understand how a flipped classroom approach can be implemented and how effective it is at helping learners to be successful in learning calculus. Through implementing the flipped classroom within my practice, I was able to develop a deep understanding of this pedagogy as well as its presence within learning calculus.

Research Methodology: Qualitative Action Research

To address the purpose of this study, I chose an action research study in which participants would be actively involved in the research process. Action research is a collaborative investigative approach that engages participants as equal and full contributors to the research project (Herr & Anderson, 2015; Stringer, 2014). This form of research design is mostly informed by the qualitative paradigm, though it is possible to collect quantitative data in action research studies. According to Patton (2002), “… qualitative methods can contribute to useful evaluation, practical problem solving, real-world decision-making, action research, policy analysis, and organizational or community development” (p. 145). Action research is about engaging in activities that “organizational or community members have taken, are taking, or wish to take” (Herr & Anderson, 2005, p. 4) to change some aspects of their situation. Argyris and Schon (1991) interpret action research as a form of self-reflective problem solving that enables practitioners to understand better and improve educational practices. For example, “a teacher might begin to wonder whether or not a particular intervention will improve the math skills of her students. She might develop an intervention strategy and study its effects over time, simultaneously engaging students in the process” (Merriam & Tisdell, 2016, p. 49). Hence, since a
problem for practice is posed in the purposive inquiry of this study, action research can be the best research methodology approach, which provides me the opportunity to creatively explore alternative ways to achieve educational success in learning calculus. This methodology provides explicitly a means to address a practice problem, such as to investigate how learners experience active learning in a formal academic context, to effect change, or improve practice (Kuhn & Quigley, 1997).

The origin of action research in education can be traced to Lewin (1940), who was influenced by Dewey and his desire to improve social conditions in contexts through action and reflection (Kemmis & McTaggart, 1988). Since then, action research has been used in many different situations and has been “designed to develop new skills or new approaches to solve problems with direct application to the classroom or other applied setting” (Merriam & Simpson, 2000, p. 122). Action research has been described as a non-linear spiral of planning, acting, observing, and evaluating with the premise of gaining insight into a process; the researcher must create a change and then observe the effects (Herr & Anderson, 2015). According to Merriam and Tisdell (2016),

action research is a form of practitioner research. It not only seeks to understand how participants make meaning or interpret a particular phenomenon or problem in their workplace, community, or practice, but it also usually aims to engage participants at some level in the process to solve a practical problem. (p.49)

Action research, with its emphasis on problem-posing and problem-solving, offers a valuable tool for teachers (Herr & Anderson, 2015; Kuhne & Quigley, 1997). It empowers teachers to take common problems, compare action research outcomes along the way, and ultimately develop a range of tested, replicated answers. In action research, the role of the
researcher is to facilitate problem-solving and provide direction to the participants of the research project (Merriam & Simpson, 2000; Stringer, 2014).

There are different types of action research with some similarities and differences. Herr and Anderson (2015) classified action research: teacher research, collaborative action research, collaborative inquiry, appreciative inquiry, critical action research, feminist action research, and participatory. However, most action research projects fall into what Kemmis et al. (2014) refer to as either practical action research or critical action research. Elliot (1994) argues that educational action research has some features not present in other forms of investigation: “it has a pedagogical aim which embodies an educational ideal and which all those participating are committed to realizing” (p.136). In other words, action research follows some principle that makes it a unique research methodology. For example: (1) it focuses on solving the problem or improve the practice;(2) design of the study is emergent in which researchers and participants engage to improve practice;(3) participants are engaged as co-investigators;(4) lead researcher is an insider or outsider to the community under study;(5) researchers and co-investigators collect and analyze the data (Merriam & Tisdell, 2016).

Several authors characterize action research by its cyclical nature as it proceeds through four distinct processes (Kemmis & McTaggart, 1998; Kuhne & Quigley, 1997; Herr & Anderson, 2015). First, a plan of action is developed to improve what is already happening in an identified setting. Second, participants act to implement the proposed plan. Third, the impact of the action is observed and evaluated. Fourth, the observations lead to further planning and action through a continual succession of cycles of observation and improvement (Herr & Anderson, 2015).
The core processes of action research are planning or deciding how to deal with a problem, acting or implementing the plan, reflecting or analyzing outcomes and revising plans for another cycle of acting, and finally, observing or paying attention and recording the observations lend themselves to the cyclical nature of lesson study (Kuhne & Quigley, 1997). With this in mind, the intention of action research to generate solutions that have immediate application in practice can help me to improve the quality of teaching calculus in higher education. I used action research for my study because it takes into the lived experience of students, a collaborative approach with participants, and a continuing, systematic process of reflection and action (Herr & Anderson, 2015). Like qualitative methods, action research attempts to understand a question or problem better. It is becoming a more widely accepted method of study as people’s experiences, their narratives, and the analysis thereof is becoming realized as useful contributions to the current research base (Stringer, 2014). This action research study encouraged me to question, analyze, and also involved me in the process of generating and testing new forms of action for realizing my aspirations and thereby in reconstructing my practical pedagogical theories and practice (Segal, 2009).

**Background of the Researcher**

On occasion, extraordinary events motivate us to accomplish a task, but my motivation for being a math instructor was otherwise. Strangely, I first became interested in mathematics education in high school, where I had a poor learning experience. My teacher’s pedagogy was so different and lacked inspiration. Her style of teaching consisted of repeating lectures to help students memorize the material rather than imparting in-depth and sustainable knowledge. Many of my classmates struggled mightily to pass the class. Several of them expressed that the class atmosphere and the method of teaching had inculcated a deep hatred towards mathematics and calculus.
Despite the many negative attitudes that could disappoint me, I decided not to let them interfere with my yearning to learn. From that point forward, the desire to be an excellent mathematics teacher grew in me and, eventually, drove me into the field of mathematics education. I earned my first master’s degree in mathematics. But, during my master’s work, I found myself wishing that I could study in a program that was more about pedagogy than only math content. Thus, I earned my second master’s degree in mathematics education. Then, a friend pointed me in the direction of Life-Long and Adult Education, which has provided an opportunity to contribute to mathematics and adult education through research on my favorite topic: teaching Calculus.

Teaching calculus is my expertise, and I have taught this subject for many years. Most of my students are freshmen within the 18 to 25-year-old age group designated as emerging adults (Arnett, 2000). However, among my students, I have had adult students within 30 and 50-years old. Today, adult learners are a significant population in higher education (Kasworm, 2010). While this group of students has accumulated life experiences and knowledge and bring unique characteristics to classrooms (Knowles, 1980; Merriam et al., 2007) when it comes to learning mathematics, they generally have one characteristic in common: they consider themselves incompetent because they think they are too old or, perhaps, no longer capable of the intellectual demands of a math classroom.

However, learning calculus is hard for most students, regardless of their age. Additionally, the way that calculus is being taught in higher education is teacher-centered, which does not motivate students or allow them the time and space to think and process ideas. Students doubt their ability to learn such an abstract discipline, and unfortunately, many of them will choose an alternative major which inhibits their aptitude to pursue their dreams.

I have come to believe that learners must take an active role in the teaching/learning environment. Students learn more when they are intensely involved in their education and have opportunities to think about and apply what they are learning in a different setting (Bressoud & Rasmussen, 2015). This form of classroom shifts the educator from an expert with knowledge to
be transmitted into a facilitator, encouraging students to become active constructors of knowledge and understanding. Based on my experience, I feel that a learner-centered classroom, along with active-learning strategies, forces students to engage the mathematical ideas and confront their misconceptions. I am interested in practical strategies that are effective at increasing student success in undergraduate science and mathematics courses—particularly for underrepresented groups of students.

This research study helped me to continue to evolve and improve the teaching and learning of calculus by creating excitement in the classroom and incorporating active learning strategies that engage students in doing rather than just listening. I planned to investigate how flipped classroom instructional strategies such as dialog, debate, writing, and problem-solving can engage students in higher-order thinking tasks as analysis, synthesis, and evaluation. Classrooms of this type shift the educator from an expert with knowledge to be transmitted into a facilitator encouraging students to become active constructors of knowledge and understanding (Amstelveen, 2019; Jensen et al. 2015).

My main concern is to facilitate student success. I am looking for a solution to the problem of high failure rates in first-semester calculus. Upon this research project, I was teaching in a traditional lecture format, which I experienced throughout my education experience. I wrote the notes on the board, and students would copy the notes into their notebooks. Communication during class time was mostly one-directional from me to the student. Students completed homework outside of class and passed it in during the following class meeting. I could see students interact outside the classroom, but I recognized they were not engaged inside the class. I was wondering if the problem was actually with me, or my instructional strategy the cause of disengagement?

In the spring of 2018, I incorporated some small learning exercises in my classes to break up lectures and noticed a difference in students’ involvement. Based on this experience, I felt that a flipped classroom would encourage more success than the current traditional model of teaching. I was interested in practical strategies that would assist other colleagues and me in the
transition. Due to the need to offer more time for students to think and process mathematical ideas, I embarked on the journey of transitioning from a traditional lecturer to a constructivist teacher within a flipped classroom.

**Participant Selection**

To explore the efficacy of learner-centered teaching, this study focused on the learning outcomes of the students by employing active learning techniques through the action research cycle of planning, acting, observing, and reflecting. In general, a qualitative study uses a purposeful sample that Patton (2002) regards as a group of participants who can offer” useful manifestations of the phenomenon of interest” (p. 40). “The purpose of purposeful sampling lies in selecting information-rich cases whose study will illuminate the questions under study” (Patton, 2002,p.169). Thus, this qualitative action research study used a purposeful sample of students who enrolled in my Calculus I, the first calculus course in calculus course sequences. In this type of sampling, a researcher consciously chooses participants based on a set of attributes that a group shares (Creswell, 2013; Stringer, 2014).

Most of the students were traditional-age students with a one adult learner among them. Sometimes adults are thought to be synonymous with “nontraditional” students. One or more of seven characteristics generally define this group of learners: delayed enrollment in education, attend part-time, financially dependent on parents, work full time while enrolled, have dependents other than the spouse, are a single parent, and lack a standard high school diploma (Kasworm, 2010; Merriam et al., 2007). Adult students have typically been defined as age 25 or older (Kasworm, 2010); however, life experience should determine whether an individual has reached adulthood as opposed to the individual’s age (Holx, 2010). Merriam et al. (2007) state that, “adult education is a large and amorphous field of practice, with no neat boundaries such as
age” (p. 53). As Holx (2010) mentioned, life experience and the context of the classroom affect both younger and older.

**Course Overview and Study Participants**

To investigate a student-centered calculus classroom, I designed a flipped classroom model for my calculus class during spring 2020. The flipped classroom is a pedagogical strategy in which the teacher serves as a facilitator. At the same time, students co-construct their learning socially and collaboratively based on their personal experiences (Bergmann & Sams, 2012).

The study took place over a 15-week semester at a large university’s satellite campus in the Mid-Atlantic region of the United States. The university consists of multiple campuses and serves a large geographic location, including numerous urban areas, and attracts a diverse student body in search of degree completion, workforce development, and educational accreditation. The study occurred throughout the spring 2020 semester in Calculus I, the first calculus course in the calculus sequence. Students might enter the course through two different methods. First, students may take the course directly based on their mathematics placement test (ALEKS). ALEKS is a powerful artificial-intelligence based assessment tool that indicates the strengths and weaknesses of a student’s mathematical knowledge, reports its findings to the students and their advisers, and then provides the students with a learning environment for improving their mathematics skills.

Second, students may progress into the course after completing a lower level of mathematics instruction such as Algebra I and II. In this context, successful completion is defined as earning a letter grade of a C or better in the course. All students, who registered for Calculus I, could participate in this study. However, participation in the study was voluntary, and students could choose to opt-out of the study at any time without fear of consequences to their course grade or treatment within the class. Our calculus classes met each week for two
minutes in class and one 50 minutes online. During the final examination week, two hours were allotted for students to complete the final examination, a standard examination (all students enrolled in the course took the same version of the test). Students could receive additional support from me during office hours, by going to one of the tutorial laboratories on campus, or by using online tutoring resources available through the university.

The study was introduced during the first class period of the semester. In the first week of classes, a colleague met with all registered students to determine who was interested in participating in the study. Students who agreed to participate signed the consent form (Appendix C) approved by the Institutional Review Board. As a general instruction, I informed students of their role in the study and their responsibilities.

To design the flipped classroom, I used Talbert’s inverted learning Model. A review of the flipped classroom implementations suggests that an effective flipped classroom experience involves highly structured pre-class assignments in which “students make the first contact with new material; a means of accountability to ensure students do the out-of-class work; well-designed sense-making activities for students to do during class; and open lines of communication throughout the course” (Talbert, 2014, p. 364), and a collection of instiinctual videos.

Every week I provided students with some highly-structured pre-class assignment (Appendix D) consisting of a brief overview of the upcoming content, including one or two lists of learning objectives, and a review of pre-calculus knowledge that students needed in order to learn new topic. Students had to be fluent in pre-calculus objectives when they arrived at the class. However, they did not have to be fluent in the new topics’ review (Talbert, 2014). I also provided a collection of videos(Appendix E) and print resources, which helped students learn
about primary and the new material. The videos were brief (preferably between 5 and 7 minutes in length) and not merely showed students how to perform mechanical procedures but also, provided perspective on the topic at hand from an expert's standpoint. Students were expected to apply what they learned in the pre-class assignments and video lectures during the various in-class learning activities (Appendix F).

Additionally, every week students completed some homework online on WebAssign (an online instructional tools) or school web-based learning management system (Canvas). The assignment was based on essential fluency and new topics. The lists of learning objectives were intended to give students a clear idea of what they are expected to know. By splitting the objectives into “basic” and “advanced,” students have a specific target to hit in their pre-class work; and importantly, it communicates to students that they do not have to know everything in the upcoming unit before coming to class. “The advanced objectives served as the agenda for the class meeting, and the union of both lists can be used later as a topic guide for exam preparation” (Talbert, 2014, p. 365). The in-class activities were based on topics presented in videos, short lecture, and/or pre-class assignments.

Initially, 28 total students were registered for the course. However, just eight students consented for the end of the semester’s interview. The eight participants were freshmen, and the first time taking calculus in college. All participants were STEM majors. Ashley was a confident young woman who was comfortable sharing her thoughts and questions in any setting. Mary (pseudonym) was a diligent mathematics student, though she was not confident in her abilities and often needed encouragement and support. Zack (pseudonym) was a high-achieving, diligent young man and liked to be challenged. Fady (pseudonym) was a quiet student who rarely spoke out in the classroom setting but was worked well in pairs or small groups with other students.
Nikki (pseudonym) was very quiet but smart. At the beginning of the semester, she seemed uncomfortable, but she was a happy student at the end. Joe (pseudonym) lacked algebra skills but took it upon himself to learn what he needed to know during the semester. Nick (pseudonym) struggled with the content in advanced mathematics but appreciated the challenge that calculus posed. Nick also asked many clarifying questions in a one-on-one setting but did not like to speak out in a whole-class setting. The participants for this study were a diverse group in age, gender, as well as mathematics skills. Table 1 gives the reader a greater sense of the participants overall. Table 1: Participants Summary

<table>
<thead>
<tr>
<th>Name</th>
<th>Age</th>
<th>Gender</th>
<th>Major</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashley</td>
<td>18</td>
<td>Female</td>
<td>STEM Education</td>
</tr>
<tr>
<td>Mary</td>
<td>18</td>
<td>Female</td>
<td>STEM Education</td>
</tr>
<tr>
<td>Zack</td>
<td>22</td>
<td>Male</td>
<td>STEM Education</td>
</tr>
<tr>
<td>Nikki</td>
<td>18</td>
<td>Female</td>
<td>STEM Education</td>
</tr>
<tr>
<td>Fady</td>
<td>18</td>
<td>Male</td>
<td>STEM Education</td>
</tr>
<tr>
<td>Joe</td>
<td>19</td>
<td>Male</td>
<td>STEM Education</td>
</tr>
<tr>
<td>Nick</td>
<td>18</td>
<td>Male</td>
<td>STEM Education</td>
</tr>
<tr>
<td>Tom</td>
<td>18</td>
<td>Male</td>
<td>STEM Education</td>
</tr>
</tbody>
</table>

Data Sources and Collection

Qualitative research typically uses three major types of data collection techniques: interviews, observations, and collection of documents and artifacts used by participants in the setting (Merriam, 1998; Merriam & Tisdell, 2016). On the other hand, the primary data collection methods were used in the action research include researcher journal, questionnaires, and interviews (Kuhne & Quigley, 1997). Triangulation refers to the use of multiple methods or data sources in qualitative research to develop a comprehensive understanding of phenomena.
Triangulation also has been viewed as a qualitative research strategy to test validity through the convergence of information from different sources (Patton, 2015). It is vital to decide on several ways to collect data in action research (Kuhne & Quigley, 1997). In this study, triangulation of the data from the researcher journal, questionnaires, minute papers, interviews, and faculty evaluation help to increase reliability and establish validity and trustworthiness (Herr & Anderson, 2015). All data collection components are described below.

**Researcher Journal**

In self-study action research, the researcher journal is a major source of data (Herr & Anderson, 2015) to record the most significant events of a researcher’s day (Kincheloe, 1991). Events and activities can change so much during a project that one can easily forget one’s earlier thoughts and feelings (Kuhne & Quigley, 1997). It is recommended that all action researchers keep reflective journals to remember what everything looked like or felt like (Khune & Quigley, 1997). Journal kept me grounded in the process, as recommended by Herr and Anderson (2005), who highlights:

> Because of this lived complex reality, keeping a journal is a vital piece of any action research methodology; it is a chronicle of research decision; a record of one’s own thoughts, feelings, and impressions; as well as a document reflecting the increased understanding that comes with the action research process. Beyond these, it is important to keep track of the ethical decisions made throughout the research process. (p. 77)

I kept a researcher journal (Appendix G) in which I wrote after each class throughout the semester. This allowed me to express my feelings, anxieties, and comments on events that have taken place or that one anticipates. Keeping my journal provided an opportunity to input my perspective within the research. It allowed me to document challenges and successes. “What
were the most significant events of the day?” (Kincheloe, 1991, p. 107), those things that worked well and those that did not. Through the journal, I expressed my feelings, anxieties, and comments on events that took place. “What is helping students learn? What is making learning more difficult? What specific, practical steps could he [teacher] and the class take to improve learning?” (Angelo & Cross, 1993, p. 340). It helped me to look in the ongoing weeks and see the moments when I felt most engaged or disengaged, connected or disconnected, and certain or uncertain. It helped me to understand my teaching techniques, active learning strategies that I want to use, and their effectiveness.

**Questionnaires**

At the beginning of the semester, I administered a survey to collect demographic information as well as students’ attitudes and perspectives related to learning calculus (Appendix H). Since action research requires a constant cycle of planning, action, and reflection (Stringer, 2007), I administrated a Critical Incident Questionnaire (CIQ) (Appendix I) biweekly to understand any techniques that should be revisited. I addition, a mid-term longer questionnaire (Appendix J) was administrated. The purpose of the was to elicit students’ experience in the course so far and what changes they would suggest. At the end of semester an open-ended online questionnaire was administered, just focusing on learning online and Zoom classroom.

**Minute Papers**

Minute papers, also known as the “One-Minute Paper” and the “Half-Sheet Response,” provides a quick and straightforward way to collect written feedback on student learning (Angelo & Cross, 1993). Minute Papers can be used in courses that regularly present students with a great
deal of new information. It works as a warm-up or wrap-up activity at the beginning and end of class sessions (Angelo & Cross, 1993).

Minute papers are efficient as they “provide manageable amounts of timely and useful feedback for a minimal investment of time and energy” (Angelo & Cross, 1993, p.148). It can be used to assess if students have learned from a study-group meeting, homework assignment, or even exam. For example, I gave the students one of the derivative formulas and their model to learn prior to coming to the class, then grouped them at the class to practice together. Since I was able to read and analyze their responses quickly, I could address their questions during class.

I addition, I used minute papers to seek student’s feedback. I used the same model that Diehl (2015) did in her research project. Students were instructed to write “what needs to be changed on one side of the paper and what is working on the other. Student responses were analyzed, and changes were made to the course based upon student input.” (p.132)

**Semi-structured Interviews**

Interviews are the most effective method to attain deep and rich data such as feelings, thoughts, and impressions of the participants in a qualitative study (Patton, 2015). Interviews, as purposeful conversations, allowed me to examine issues such as attitude about learning calculus. It helped to gain information about the past and the present of each participant. These interviews will enable the researcher to acquire knowledge that may not have emerged from questionnaires or journals (Patton, 2015).

This study employed a semi-structured interview (Appendix K) due to their ability to be developed in advance and to ensure that all participants are addressing the same questions, but at the same time permit the participants the freedom to respond to interview questions based upon
their perspective (Patton, 2015). The semi-structured interviews “involves asking more open-ended questions of several participants but allows the interviewee to go further than the precise question with opinions, thoughts, and questions” (Kuhne & Quigley, 1997, p. 40). According to Patton (2002), “open-ended interviews add depth, detail, and meaning at a very personal level of experience” (p. 17). The benefit of this process is that it offers a format to the researcher to maintain a consistency of content across research participants. During the interview, extension questions or prompts were used to acquire additional information and clarity (Hatch, 2002; Springer, 2014).

The semi-structured open-ended interviews were scheduled with 8 participants during the last week of the semester. The technology used to facilitate the electronic interviews was electronic conferencing software, Zoom, which has the advantage of recording an electronic meeting as a video directly to a computer. In addition, anything that occurs in a Zoom meeting remained there until it is physically deleted, and Zoom does not require any particular app or software, unlike other teleconferencing tools. Interviews were recorded and transcribed using Kaltura. Transcripts were available to participants to ensure their thoughts were captured as intended.

**Faculty Evaluations**

The Student Rating of Teaching Effectiveness (SRTE) is an instrument for gathering feedback from students at the end of the semester. This focus on four themes: student’s motivation to take the course, the frequency that the instructor used specific teaching procedures, how the course has helped the student progress in certain areas, and rating of the course and the instructor. Students complete the faculty evaluation using a seven-point Likert scale. “Survey data includes the number of students that did not respond to each question. Basic statistical
analyses with percentages were calculated in each of the 17 criteria” (Diehl, 2015, p.133). In addition, the survey has four open-ended questions that illustrate students’ feedback about the course and instructor. What helped them learn in this course? What changes would improve their learning? What did they like the most or what they liked the least?

**Data Analysis**

Since qualitative research studies typically generate so much data, determining which data are significant is the most challenging task (Kincheloe, 2003). Data analysis requires a skillful interpretation and relies on a systematic and rigorous method. Thus, some have described the qualitative analysis as craftsmanship, others as an art, and still others as a process of detective work (Patton, 2002). Data analysis of all qualitative data focused on providing a “thick, rich description” (Patton, 2002, p.437). This thick description allows the reader to “understand the phenomenon studied and draw [their] own interpretations about meaning and significance” (p.438). In qualitative research analysis, the attempt is made to discover patterns and insights from the data. However, “we have few agreed-on canons for qualitative data analysis, in the sense of shared ground rules for drawing conclusions and verifying their sturdiness” (Miles & Huberman, 1984, p. 16), which undoubtedly presents the qualitative researcher with an unwanted realization.

In this study, I used inductive analysis and working towards the identification of common themes and patterns among the data (Patton, 2002). An inductive approach means the researcher is immersed in the details and begins his or her work by exploring, confirming, and ending with synthesis. The purpose of inductive design is that themes emerge from examining perspectives and explanations of key findings to the study (Patton, 2002). The participants contributed by verifying the themes as I began to write the findings section.
As action research is a cyclic process of investigation that comprises four main stages: planning, acting, observing, and reflecting (Kuhne & Quigley, 1997), I revised the plan after each cycle, especially in the light of the experiences gained through observation and reflection. Keeping true to the action research process, I reviewed the data gathered from the participants every two weeks and reflect after each activity to determine the next action. To form a complete picture of what occurred throughout the study, any apparent and missing data were considered. In my analysis of the weekly data, I used my researcher’s journal to reflect on what I know about the participants’ beliefs about the techniques that I used and why they think they worked or did not work. This reflection stage determined which learning activities should be included or modified before moving to the next action phase.

In this research, data were collected using an electronic interview method. During the data analysis phase, the interview results were transcribed. The themes were then categorized by interview questions, and participants’ excerpts were added to the related themes. I took all my efforts to fairly represent the data from the individual interviews, researcher journal, classroom observations, and minute paper, and analyze them based on the purpose of this study (Patton, 2002). Participant responses to the open-ended questions were analyzed for common themes and developing patterns. Open-ended questions and interview responses were analyzed by “grouping together answers from different [participants] to common questions.” (Patton, 2002, p.440)

I analyzed the data that I earned through the study and evaluated the overall leaning process. In the process, I “created a documented comparison based on the results” (Kuhne & Quigley, 1997, p.30) and code the data to highlight themes and compare the interpretations of the results of the participants and the process of the action research to look for consistency in understanding.
Due to the nature of an action research study, a researcher should expect to potentially shift the questions, methods, and design, as the data is collected and analysis begins to unfold (Herr & Anderson, 2015). This feature of action research helped me when I had to shift face-to-face to the Zoom classroom. For action research, this shifting is undoubtedly an essential component of the continuous interacting spiraling of reflection and action; in turn, data analysis is continuous (Herr & Anderson, 2015; Stringer, 2014). Therefore, the trustworthiness of a qualitative action research study lies in the willingness of the participants to make meaning and intervene to create change (Herr & Anderson, 2015). This is discussed in the following section.

To protect participants’ anonymity, a contact list was created, and the participants’ names were replaced with pseudonym names so that the information they provide cannot be linked to their identity. Regarding confidentiality, all electronic data received from the participants was saved on a password-protected computer. Any written info associated with this study was stored in a locked file cabinet in the researcher’s office.

**Trustworthiness of the Study**

Miles and Huberman (1994) stated: “still the problem of confidence in findings has not gone away…We need to keep working at sensible canons for qualitative data analysis, in the sense of shared ground rules for drawing conclusions and verifying their sturdiness” (p. 271). Qualitative research is an interpretive and holistic approach (Denzin & Lincoln, 1994). This means that qualitative research study phenomena in their natural settings, attempting to make sense of or interpret them in terms of the meanings that people bring to them (Merriam, 2009). Therefore, because of the role of researcher, intuition, and potential bias in, the questions that arise in a qualitative study are how the trustworthiness of study findings can be demonstrated?
Merriam and Tisdell (2016) specified validity and reliability should be the researcher’s concerns. According to them, these concerns can be approached through careful attention to a study’s conceptualization and how data are collected, analyzed, interpreted, and also presenting the finding. For doing this, they offer some strategies such as; (1) triangulation; (2) member checks/ respondent validation ;(3) adequate engagement in data collection ;(4) researcher’s position or reflexivity; (5) peer review/ examination; (6) audit trail; and (7) detailed, thick descriptions. In this light, to establish the trustworthiness of my research and its findings, I thoroughly and carefully considered the credibility and honesty of my actions in what Miles and Huberman (1994) regard as research worthiness, integrity, and quality.

Precisely, I discuss four measures of trustworthiness: credibility, transferability, dependability, and confirmability (Table 2). I review how the reliability of my qualitative findings enhanced through careful attention to a study’s conceptualization and how the data are collected, examined, and understood.

Table 2: The Four Criteria of Trustworthiness in Qualitative Research (Guba & Lincoln, 1989)

<table>
<thead>
<tr>
<th>Criteria of Trustworthiness</th>
<th>Parallel</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Credibility</td>
<td>Internal validity</td>
<td>Truthfulness—the extent to which observed results reflect the realities of the participants in such a way that the participants themselves would agree with the research report.</td>
</tr>
<tr>
<td>Transferability</td>
<td>External validity</td>
<td>Applicability—the extent to which observed results are</td>
</tr>
<tr>
<td>Dependability</td>
<td>Reliability</td>
<td>Consistency—the extent to which observed results would be similar if similar research were conducted in the same or a similar context.</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Confirmability</td>
<td>Objectivity</td>
<td>Neutrality—the extent to which observed results reflect the actual context of participant experiences, rather than simply the researcher’s perspective.</td>
</tr>
</tbody>
</table>

Adapted from Privitera (2017, p. 214)

**Credibility**

The basis of any claim to trustworthy knowledge is credibility, which establishes that the representation constructed through research is indeed valid and believable. In other words, credibility pertains to how well the research findings represent reality (Merriam, 1998). It refers to the attention paid to fieldwork and other means of the study to ensure trustworthy data is collected and analyzed (Patton, 2002). According to Bloomberg & Volpe (2008),” credibility suggests whether the findings are accurate and credible from the standpoint of the researcher, the participants, and the reader” (p. 86). To maintain credibility in this study, a number of factors are considered. First, however, my readers should understand that credibility doesn’t mean truth-value. Truth in qualitative research is not absolute and generalizable (Merriam, 2009); “truth . . .
means reasonably accurate and believable data rather than data that are true in some absolute sense” (Patton, 2002, p. 578). Truth and findings in this study will be created based upon contextual influences in a particular setting.

This action research study engaged the researcher and participants for an extended time. Besides the length of study (fifteen weeks) and prolonged engagement of the participants, which increase the credibility of the study, a detailed description of the interviews and direct quotes from the transcript certified the trustworthiness of data and its analysis. The responses were recorded during a virtual meeting and subsequently transcribed. The participants were then asked to review the interview reports to ensure that their responses were correctly interpreted. Most participants confirmed that the words were correct. Only one participant suggested one minor revision in his statements; the reports were immediately updated and verified with him again. The other thing that enhanced credibility was triangulation. Triangulation means to use multiple methods, sources, and perspectives or theories to interpret the data (Merriam & Tisdell, 2016; Patton, 2002). While the purpose of triangulation is not to confirm that the different data sources lead to the same results, it helps the researcher to test consistency between the data sources (Patton, 2002).

Furthermore, minimizing the researcher bias enriched credibility. This was done through member checks in which participants were asked to validate the accuracy of data analysis from their perspectives (Merriam & Tisdell, 2016). Kincheloe (1991) encourages researchers to share portions of their journal with participants and ask them to provide feedback about the accuracy, completeness, and fairness of the study. Besides, I kept a journal to record the emerging understandings, which provided a level of reflexivity. This reminded me to maintain a high level
of awareness during the study and to continually try to understand what I learned about the students’ assumptions and beliefs about my teaching and attitude.

Transferability

The next step route to trustworthiness is the degree to which the representation and findings are applicable beyond the particular setting or inquiry (Patton, 2015). Transferability is about the potential of the study to be generalized. It is concerned with if the finding of the study can be applied to another context and whether or not similar results can be expected.

To make the reader able to determine what aspects of a particular study with its specific context could be applied to their classroom or similar situations (Bloomberg & Volpe, 2008), I provided any supporting materials and documents that were utilized in the study. In general, qualitative research seeks transferability by giving details of the phenomena. This can be achieved by a thick description that provides “the database that makes transferability judgments possible on the part of potential appliers” (Lincoln and Guba, 1985, p. 316). Thick and rich description “takes the reader into the setting being described” (Patton, 2002, p. 437) and explains events such that the reader can feel that they experience the events described. According to Denzin and Lincoln (2005), “the thicker the description that can be produced, the subtler the interpretations that can be made” (p. 711). They further suggest that thick description makes thick interpretation possible.

As mentioned before, qualitative research is not generalizable (Merriam&Tisdell, 2016; Patton, 2015). In this action research study, transferability could only be a specific group with the same criteria used in the selection process. This means my study might not be applied in different situations. However, the process that I went through in applying learner-centered teaching and action research activities can be replicated in future studies and the classroom. As
Merriam (2002) suggests, the reader of the report can determine the extent to which the findings of the study can be applied to a particular situation.

**Dependability**

Dependability is another central issue in a qualitative study that should be considered regarding this action research study. Dependability ensures that the researcher is “consistent and dependable with the data collected” (Bloomberg & Volpe, 2008, p. 86). In other words, dependability examines if the findings can be trusted regarding consistency, quality, and thoroughness (Patton, 2002).

Dependability of this study can be verified through a thick and profound description of data and documentation of researcher thoughts and analysis, which Patton (2002) named as “intellectual integrity” (p. 553). I documented the transparency of my process of action research. I used the audit trail, which requires an outside person to review and examine the research process and the data analysis to ensure that the findings are consistent and could be repeated (Merriam & Tisdell, 2016). Dependability strategies, also referred to as internal validity, ensure that the “results are consistent with the data collected” (Merriam & Simpson, 2000, p. 102). Through the use of the audit trail, this study used a systematic process of data collection and analysis and provided a dense description of the process to increase its dependability. In doing so, the attempt was made to provide enough transparency to determine the closeness of the interpretation of reality.

**Confirmability**

Confirmability is the degree to which data can be validated and stems from the question of whether or not the research’s findings can be confirmed. With qualitative data, confirmability is established through direct, frequent, and repeated affirmation of the research records such as
journals, field notes, and interview transcripts. I made my best effort to analyze the finding based on participants’ responses and not my potential bias or personal motivations.

Confirmability is the “relative neutrality and reasonable freedom from unacknowledged researcher biases – at the minimum, explicitness about the inevitable biases that exist” (Miles & Huberman, 1994, p. 278). In other words, it is trying to limit the researcher’s bias in interpretation. While a researcher cannot remain entirely objective, there are strategies to reduce researcher bias. In this study, an audit trail was maintained that includes the raw data collected, researcher analysis notes, data reduction notes, field notes, and preliminary conclusions (Lincoln & Guba, 1985). In addition, multiple types of data sources (interviews, journals, field notes, observations) together in a similar interpretation will provide data triangulation, strengthening its confirmability over an interpretation using only one method of data collection (Lincoln & Guba, 1985).

Summary

This chapter discussed the methodology that was chosen for the study with an outline of the core assumptions of qualitative action research. It also described the selection and use of a purposeful sample of participants, data collection techniques, and methods to analyze and interpret the data. The chapter concluded with the discussion of the trustworthiness of the study regarding credibility, dependability, transferability, and confirmability. In the following chapter, I will provide the result of my study in face-to-face flipped classroom.
CHAPTER 4

FINDINGS: FACE-TO-FACE CLASSROOM

The purpose of this action research study is to explore how learners and the instructor experience learning Calculus One (Calculus I) when active learning is implemented in a face-to-face and virtual classroom. Due to the exceptional circumstances (COVID-19 pandemic) forced upon everyone, educational setting included, three more research questions were added after the COVID-19 pandemic. Therefore, in this chapter (Chapter Four), I provide a detailed narrative and explain the planning, action phase, and overall finding for the face-to-face flipped classroom. Chapter Five will explain the planning, action phase, and overall finding for the virtual flipped classroom. To explore this purpose, in this chapter, the following research questions guided the study:

1. Does active learning promote a community of mathematical inquiry in a face-to-face college calculus classroom?
2. What is the perception of the instructor, as a researcher, concerning active learning in a student-centered face-to-face college calculus course?
3. What are the experiences and perceptions of students regarding how active learning techniques like flipped learning classroom affects their learning?

Planning for Face-to-Face Flipped Classroom

Calculus I is considered the gateway course for the majority of STEM majors. Many students struggle with the concepts and techniques included in or required in this course or fail to make connections between calculus and other science courses. Calculus I is a four credits course
with a universal course content depending on the credits. It is transferrable to almost all colleges nationwide and worldwide. This course is the foundation of physics, engineering, chemistry, and other science courses. Therefore, an in-depth understanding of this course’s content can build a solid foundation for other courses. Unfortunately, many students enroll in the course without a solid algebra and trigonometry background or with a fear of calculus instilled in them by other students or both. Consequently, it is essential that an instructor of calculus be able to use various teaching techniques and assessment tools to make sure students learn the concepts and discuss and apply them. This is particularly important due to the nationwide uniformity of course content.

Active learning in a flipped classroom teaching environment with the augmentation of various tools such as videoclips, online homework, and pre-class assignments was chosen to address this scenario. The flipped classroom is a pedagogical strategy in which the teacher serves as a facilitator. At the same time, students co-construct their learning socially and collaboratively based on their personal experiences (Bergmann & Sams, 2012).

This action research study focused on exploring a teaching methodology that creates a more active student involvement and student-centered classroom environment. A biweekly Critical Incident Questionnaires (CIQ) regarding students’ perceptions, weekly pre-class assignments, researcher journal, and minute papers were used to assess learning outcomes and students’ perception. By using this data collection, I was able to revise some of the features of flipped classroom teaching while preserving the course integrity, syllabus and learning goals.

Constructivist scaffolding practices and social constructivist principles were the main guiding philosophies of this study. The study took place over a 15-week semester at a large university’s satellite campus in the Mid-Atlantic region of the United States. The university
consists of multiple campuses and serves a large geographic location, including numerous urban areas, and attracts a diverse student population in search of degree completion, workforce development, and educational accreditation. Initially, 28 total students were registered for the course. However, just eight students consented for the end of the semester’s interview. The eight participants were freshmen, and the first time taking calculus in college. All participants were STEM majors.

The flipped classroom model moves direct instruction out of the classroom, leaving class time for more collaborative and active assignments. The idea to design the flipped model was formed by Dewey’s (1938) with the focus on education as a student-centered practice, and Vygotsky’s (1978) with the assertion that learning occurs through social interaction. As the literature reviewed indicated, active learning strategies allow students to participate collaboratively in understanding mathematics. Classroom activities enable students to learn together by increasing their interactions. A review of the flipped classroom implementations suggests that an effective flipped classroom experience involves highly structured pre-class assignments in which “students make the first contact with new material; a means of accountability to ensure students do the out-of-class work; well-designed sense-making activities for students to do during class; and open lines of communication throughout the course” (Talbert, 2014, p. 364), and a collection of instinctual videos.

Every week I provided students with some highly-structured pre-class assignments (Appendix D) consisting of a brief overview of the upcoming content, including one or two lists of learning objectives, and a review of pre-calculus knowledge that students needed to learn a new topic. Students had to be fluent in pre-calculus objectives when they arrived at the class. However, they did not have to be fluent in the new topics’ review (Talbert, 2014). I also
provided a collection of videos (Appendix E) and print resources, which helped students learn about primary and the new material. The videos were brief (preferably between 5 and 7 minutes in length) and not merely showed students how to perform mechanical procedures but also provided perspective on the topic at hand from an expert’s standpoint. Students were expected to apply what they learned in the pre-class assignments and video lectures during the various in-class learning activities (Appendix F).

Every week, students completed some homework online on WebAssign (online instructional tools developed by Cengage Publishing) or school web-based learning management system (Canvas). The assignment was based on essential fluency and new topics. The lists of learning objectives were intended to give students a clear idea of what they are expected to know. By splitting the objectives into “basic” and “advanced,” students have a specific target to hit in their pre-class work; and importantly, it communicates to students that they do not have to know everything in the upcoming unit before coming to class. In this way, “the advanced objectives served as the agenda for the class meeting, and the union of both lists can be used later as a topic guide for exam preparation” (Talbert, 2014, p.365). The in-class activities were based on topics presented in videos, short lectures, and/or pre-class assignments.

I broke 15 weeks of the spring semester into five primary learning objectives: Functions (definition & types), limits of functions, derivatives (instantaneous rate of change of a function), application of derivatives, integrals (areas under the graphs of functions), and applications of integrals.

Every Friday evening, I provided students a video, a set of pre-class assignments, and a brief overview of the upcoming content, which gave students an idea of the new topic and its relation to materials learned. The presentation of content via the instructional videos enabled the
students to pause the video and repeat the instruction sections as necessary, an option not always afforded to students in a lecture-based classroom setting. Students were instructed to take notes of the examples presented in the video lessons and record clarifying questions in their notes to bring to the class. The pre-class assignments helped students review algebra, trigonometry, or pre-calculus skills needed to learn a new topic. Students had to be competent in pre-class assignments when they arrived at the class, but they didn’t have to be knowledgeable in the new topic’s review. During class time, the students applied their knowledge. They worked in small groups or partners on various tasks, including practice worksheets, graphs, or explorations, to tackle the new topic’s problems. Students who needed clarification with the material could interact with a classmate or ask me for an additional explanation as they made meaning of the material.

I created a course calendar on our instructional platform, Canvas. The course calendar included all homework assignments and due dates for quizzes and exams. The calendar helped students to see the class plan. It also was created to assist students with time management and planning. Students appreciated the course’s organization and commented that it summarized their tasks each week and helped them remember what they need to study, assignments due, recorded lectures to watch, and live sessions. Sometimes I had to revise the calendar after assessing the learning taking place (and whether or not a specific topic needed more time) and receiving feedback from the students through class discussion and the biweekly Critical Incident Questionnaires (CIQs).

In the flipped classroom design, activities no longer focused on passive learning through listening to a lecture. Instead, students were engaged in active learning strategies such as entrance quizzes, error analyses, concept maps, questions from homework, roundtable exercises,
minute papers (Angelo & Cross, 1993), and function creations (See Appendix F for a detailed description of each active learning strategy was used). The active learning strategies were utilized in individual, partner, small group, and whole-class discussions and presentations. The intention was to encourage students to listen, share, synthesize, question, write, justify, defend, and discuss in class each day instead of just listening and writing (Diehl, 2015).

At the start of every class, students had to complete a one or two questions entrance quiz to assess their out-of-class preparation. These quizzes took about 5 to 10 minutes. I typically asked the students to write down a formula introduced in the pre-class assignment or solve the same problem demonstrated in the videos. The entrance quizzes were graded and accounted for about 2% of the final grade. After a concise lecture on a new topic, I utilized one of the in-class learning activities. Class time was primarily a work session where the students and the groups were expected to complete an in-class activity. Students were typically expected to present solutions to other students in their group. This occurred in a variety of ways. Sometimes an individual student from a group would present their group’s solution to the entire class. Other times, several students from a group would present the solution together, each explaining part of the solution.

While the students worked on the problems, I circulated through the room, answering students’ questions, and providing them feedback on their progress. When necessary, I checked notes from the videos, conducted mini-lessons, interrupted the class, and conducted whole-class discussions, retaught a concept to expand an idea or clarify misunderstandings. I monitored all groups to keep them active. When groups appeared to be finishing, I would direct them into the next learning activity.
In this study, data collection consisted of five types of data: researcher journal, questionnaires (including critical incident questionnaires), minute papers, interviews, and faculty evaluations. At the beginning of the semester, I administered a questionnaire to collect demographic information and students’ attitudes and perspectives related to learning calculus (Appendix H). Since action research requires a constant cycle of planning, action, and reflection (Stringer, 2007), and I wanted to understand when and how students were most invested, any topics that should be revisited, or any techniques that should be revised, I administrated a bi-weekly Critical Incident Questionnaires CIQ (Appendix I) at the end of week two, four and six, and ten.

A mid-term longer questionnaire (Appendix J) was administrated at the end of week eight. The purpose was to elicit students’ experience in the course so far and what significant changes they would suggest. This data was part of the observing and reflecting stages in action research and helped guide future sessions (details below). Additions or changes to the course calendar, videos, pre-class assignments, and homework based on student interest did occur. The semester calendar was revised a few times throughout the semester to reflect data collected from the CIQ and mid-term survey. The last questionnaire was administered at the end of the semester to elicit students’ perception of the Zoom classroom and its challenges.

**Action Phase and Overall Findings for the Face-to-Face Flipped Classroom**

In this section explaining the findings of the study in the face to face part of the flipped classroom, I have set the discussion up in two week blocks and discuss the findings that emerged from these blocks.

**Weeks One and Two: The Challenges of Getting**

The participants who were offered the opportunity to participate in the study were all those
in my Calculus I class. On the first day of class, I was apprehensive about whether I would have enough participants who would be willing to participate in the study. We began the class on August 25. The study was introduced to the enrolled students during the first class of the semester. A colleague met with all registered students and explained the study to find out if there are students who may not wish to be part of this study. Students who opted to participate signed a consent form approved by the University’s Instructional Review Board (Appendix C).

Originally, 28 total students were registered for the course. During the initial call for participants, which took place during the first class meeting. However, only 8 students consented to the exit interview. In order to focus primarily on students who also participated in the interview, the study ended up more focusing on eight participants, all able to give a final exit interview. The participants for this study were a diverse group in gender, race, ethnicity, orientation, and mathematics course experience. Later in the same first class, I met with the students, explained the details, and assured them that their responses have no bearing on their grades.

The tables below illustrated a tentative schedule for the first two weeks of the semester (the rest of the weekly schedules can be found in Appendix L). Since action research is flexible and evolving, the tables were provided simply as a guide.

Week#1

<table>
<thead>
<tr>
<th>Objective(s)</th>
<th>Different forms of Functions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Class Assignments</td>
<td>Watch video#1 and take the notes.</td>
<td>Do pre-class assignment #1</td>
</tr>
<tr>
<td>In-Class Activities</td>
<td>Discuss syllabus and course requirements.</td>
<td></td>
</tr>
</tbody>
</table>
Discuss the action research study—complete beginning of semester questionnaire 
Function creation 
Complete informed consent form.

| After-class Activities | Homework#1 |

Week#2

<table>
<thead>
<tr>
<th>Objective(s)</th>
<th>Limits</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Class Assignments</td>
<td>Watch video#2 and take the notes.</td>
<td>Quiz#1</td>
</tr>
<tr>
<td></td>
<td>Do pre-class assignment #2</td>
<td></td>
</tr>
<tr>
<td>In-Class Activities</td>
<td>Entrance quiz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concept map</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Function creation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Complete Critical incident questionnaires #1</td>
<td></td>
</tr>
<tr>
<td>After-class Activities</td>
<td>Homework#2</td>
<td></td>
</tr>
</tbody>
</table>

On the second day, I gave the students a syllabus and a review of my research project (Appendix B). I then discussed my research and flipped learning in general. I gave students the option to participate in the flipped classroom or transfer to another professor’s class. No one chose to move out of this class. However, the class tone seemed to be one of uncertainty and fear of the unknown and a desire to be involved in a new experience in their college education that they had not previously encountered. Many expressed this fear in their first week’s questionnaire (Appendix H). There are three main findings that were apparent in these two weeks, centering around mathematics as a challenge in and of itself, my own challenges as the instructor, and the flipped classroom as a response to these challenges.
Mathematics as a Challenge

The beginning of the semester questionnaire was administered on the first day of class. It illustrated the students’ initial beliefs about mathematics. Based on the analysis of the open-ended questions, many students viewed mathematics as a subject of struggle and frustration. Students’ attitudes towards learning mathematics had been impacted primarily because the content of previous math classes did not prepare them for the class they were taking or because they had a bad memory of an incident at an earlier class. For example, one student said, “I can get frustrated sometimes, and I just wish I was smart enough to understand.” Or another response was, “when I’m stuck... I feel like I have failed.” One student mentioned an emotional issue and stated, “it’s frustrating that I can’t solve it; I get mad and stressed.” Another example that was mentioned in the questionnaire was: “it is a huge challenge, and it can be very frustrating, and I just want to be able to solve it. I get angry sometimes because I’ve tried so many ways.”

A student commented,

I never took Calculus, but Mathematics, in general, means a class I have always struggled with. It always has a negative message for me because it’s the only subject I’ve ever had problems with. The word mathematics brings up a lot of memories of homework problems I didn’t understand and staring blankly at equations on aboard.

In addition, Nick expressed his feeling about mathematics at the beginning of the semester and he commented,

[Before] The first thing that came to my mind when I heard the word “math” was numbers. I thought math is definitely something that I won’t use Often and a class that won’t be one of my favorites. I never used most of the math that I have learned. When I took this class, I thought, when do I want to use a
derivative of a function or limit of the graph? I took it since I am a science person; math is something that I will have to deal with for the rest of my life.

The result of the first questionnaire was evidence of personal concerns and fears related to students’ ability to learn calculus. Nevertheless, my feedback and questioning process that I used each week encouraged participants to reflect on their concerns and fears, factors causing them, and ways to overcome them by working collaboratively with others in their small groups and class as a whole.

In the second week, students began to demonstrate some interest in the flipped classroom. This was evident in their responses and their interchange back and forth between each other, as they discussed in the groups’ activities. Mary noted her struggle with mathematics, and she confirmed that flipped learning and hands on activities changed her perspective since she said,

Before, when I heard the word math, the first that came to my mind was numbers and equations, many equations that don’t make sense to me. So many rules and theories and, of course, a grumpy teacher. But now, my perspective changed. I look at it differently. I want to try even though I get frustrated.

Often, I asked students to give me their feedback about the flipped classroom and their thoughts about my role as a facilitator so that I could think about my responses and any of the issues that they bring up. Students used WebAssign to do some homework and emailed their questions through the canvas. From my perspective, it was interesting to see what each student took from this experience. Some students had already shown to be very adaptable and very motivated to do flipped learning. However, a few students were complaining and showed resistance.
First-week Instructor’s Challenges

Flipping a calculus classroom was not as easy as I thought it would be. I should admit that I was disenchanted because the students were not always receptive to the activities designed to help them better understand the mathematics they were learning. Transition to active learning began with many unexpected challenges. Almost all students didn’t know about and had never experienced flipped learning. Students were afraid of this change, and at the beginning of the semester, they kept asking if this model impacts their grades. My first journal entry for the spring semester was:

Despite all its apparent advantages, it seems students don’t know how to appreciate active learning fully. They got used to the traditional classroom, which relies on memorizing information passed down by their teacher. They think they learn if I simply stand in front of the whiteboard and show them procedures. Many of them just wanted to know the correct path to solve a problem and nothing else. Some students do not take the time to study at home, and they are not performing well in the classroom activities. They may not be accustomed to this model; they might lose their bearings (they don’t know what to do) in the flipped classroom. (January 17, 2020)

These challenges were mostly in the first week since students believed that mathematics is some computational technique with no meaning. I noted in my journal about a conversation with a male student when he said, “mathematics should be taught using lectures, and mathematics is a collection of procedures that should be memorized to pass the class. (January 17, 2020)

Another issue was students’ inability to get immediate help/feedback while they study at home. Students who needed help during out-of-class activities usually had to take notes, write down questions, and wait for in-class discussions to obtain answers. After I got students’
feedback, I modified the procedure and eliminated this problem by utilizing discussion boards to offer instant feedback during out-of-class activities.

**The Flipped Classroom as a Learner-centered Environment**

The flipped classroom maximized the implementation of a communicative, student-centered learning environment. One of the essential goals of the flipped classroom was to move beyond the lecture as the primary way that I used to deliver information and structure class time. It allowed me to introduce new ways of doing things and focus on other ways to enhance learning by introducing active learning strategies that put students in the center of the learning experience. It shifted my class from a teacher-centered learning environment to a learner-centered learning environment and from individual to collaborative strategies.

Fady commented, “flipped learning allowed me to work at my own pace and learn how to work with a group.” Another participant, Nikki, stated, “I was engaged. I liked it when I was able to argue with you about derivative, critique, and finally, find that you are right and I was wrong. Then, I began taking ownership of my learning.” Mary also liked the flipped classroom when she said, “it [flipped learning] places the spotlight on the students and their collaborative learning activities rather than the instructor. I liked it when we were able to collaborate, and we share our personal experiences.” Then she continued and said,

I enjoyed this form of learning since it gives us time for discussion, ask questions, and interact in real-time with my classmates. In other words, rather than being alone at home when working through complex topics or homework questions while studying, we benefit from your presence, coaching, and guidance.

In the flipped classroom, my role changed from a gatekeeper of knowledge to a facilitator. I reflected on this in my journal and wrote:
Flipping has allowed me to move from an instructor-led classroom environment to a learner-centered learning environment. Now, I have to shift the focus away from myself and toward the students. I developed and used many active learning activities to enhance my student learning. It is allowing me to focus on higher-order thinking skills during class when I ask students to review pre-class activities and then come to class for more in-depth discussions about a particular topic that involves analyzing and synthesizing. (January 21, 2020)

Given the nature of a student-centered classroom, I was able to identify students struggling with understanding concepts and provide the support necessary for success. Ashley revealed her belief on why she was not good in calculus when she was in high school:

Memorization will never get you anywhere. That’s the thing that took me forever to learn. That’s probably why I struggled for a long time. If you just memorize the pattern and keep going, when you get to this level of math, you can’t do that anymore.

These statements support the premise that a flipped-classroom approach was helpful for students. It helped them stay focused during a long day at school and pay attention instead of being bored. They can reflect on their learning to integrate their new knowledge into existing schemas. Additionally, students were encouraged to actively think and solve the problem with the teacher as a guide.

**Weeks Three and Four: In-class Learning Activities and Class Environment**

Moving through the phases of action research, this study was informed by the ongoing planning, observation, and reflection of both the students and me as the instructor. To obtain qualitative data, I intended to discuss the flipped classroom on a one-to-one basis with many students during the observation phases. This would allow me to ask more probing questions as to
how students felt about flipped classrooms and how it impacted their learning. Several changes were made to the course content based on expressed student need and my observations. Throughout the research period, I reflected every two weeks and adopted the changes to support my students. This was a significant part of the action research. I had not implemented a flipped classroom before, and I needed to be sure I was implementing techniques that would benefit students. I was always careful in my responses to students’ concerns in the class or through emails to not discourage or criticize participants and offer encouragement, support, and praise to keep morale and enthusiasm high. This seemed to work well because students indicated that they were so comfortable asking questions without fear and sharing more personal feelings, beliefs, and visions than I ever thought as a possibility. Joe stated,

I am happy to take this course with you. You teach us in a way that is easy to understand.

Also, I feel comfortable asking questions, and I am not afraid to be wrong because I know that I can just stop in your office physically or virtually, and you walk me through step by step. I feel you are approachable.

The students were very comfortable with me and knew that I had absolute faith in their ability to implement this learning experience. In fact, several students told me at different times throughout the semester that I was their inspiration for working as hard as they did to make the experience successful.

I made some changes for weeks three and four. To engage students, I created more group activities to encourage students to become active learners. They started taking a dynamic and energetic role in the class. The transition from being a passive learner to taking an active part in the learning process was critical for active learning. A student noted, “I like flipped design
because it makes us attentive and forces us actively working on the problems that you’re giving us. I think that motivated me to push myself to try and understand.”

Fady revealed the same view and stated, “The activities were fun. It makes calculus a lot easier to tolerate. I actually enjoy the class.” He went on to say,

[Learning Calculus] was one of my best experience that I’ve had in this semester, I would say your class and you as a professor was, like, my best professor. The quality of learning was great. You have understood our situation, helping everyone but still making sure that everyone was involved.

I used the time in class and let the students collaborate with their classmates on practice problems or other hands-on activities. One activity I used to promote collaboration was a two-round jigsaw method. In Round 1, students would form groups of four or five students. Each group was given a specific problem. The group members worked on the problem so that by the end of Round 1, every member of the group was able to explain how to solve the problem. At the end of Round 1, the group members would number off. To start Round 2, new groups were created based on the number. This allowed the groups in Round 2 to have a member from each different group from Round 1. During Round 2, each group member shared the problem they were provided in Round 1 and explained how their group solved the problem. In this way, every student had the opportunity to collaborate with peers to solve a problem and have the opportunity to teach their peers, which is considered one of the highest levels of understanding.

In the fourth week, I was very impressed with the class’s energy and input into the activities. Classroom activities no longer focused on passive learning by listening to a lecture. Instead, students were engaged in active learning strategies such as error analysis, notes comparison, roundtable exercise, creation of practice quizzes/exams, minute paper (Angelo &
Cross, 1993), jigsaw, and thought-provoking questions. (See Appendix F for a detailed description of each active learning strategy to be used.) The active learning strategies utilized individual, partner, small group, and whole class discussion and presentations. It was the intent to encourage students to listen, share, synthesize, question, write, justify, defend, and discuss in class each day instead of just listening and writing. Students made comments indicating that the pre-class and in-class activities and videos made the class more engaging. Comments on the week four questionnaire reflected the students’ attitude when one of them said, “Unlike my other classes, calculus keeps me awake and wanting to understand more about the subject.” Another student made a very positive comment and stated, “I LOVE THE ACTIVITIES DONE IN CALCULUS!!!...they really help to break the monotony, and they cater to those of us who learn by doing, not watching. I have thoroughly enjoyed Calculus so far. It is one of my favorite classes.”

**Frustrated in a Good Way**

The questionnaires demonstrated that some students viewed learning calculus as frustration at the beginning and enjoyable at the end. Fady noted,

> Math, for me personally, has always been a favorite subject because it’s like a puzzle. If you know what you’re doing, finding the right answers, always you get that joy of excitement. Calculus, what I like most about it is how different it is, I guess because every math class until now has just been building on this is how to add this, to subtract this, how to graph things. For the most part, the experience was good. I personally did spend a lot of time being just frustrated, like frustrate me that I couldn’t get this nice answer, right? Frustrated that I couldn’t get something working, but not like frustrated in a bad way. Frustrated, as I want to get it.
Nick continued this conversation and stated,

Calculus was really new and weird. And that’s what I liked about it.

Although mathematics (specifical calculus) is not my most vital subject, I feel that my understanding has increased significantly this semester, and the flipped classroom helped in that way.

**Enjoyable Experience**

Students found the class to be a pleasure source as they were pleased with their grades and understanding of course content. Zack noted,

I have enjoyed this class; it has made me think at least once about changing my major to math...I have never had a teacher, especially a math teacher, show as much enthusiasm or love for teaching as you have. This has been my favorite class. I’ll miss it.

Mary was agreed with him when she said,

I would say it [class] was really amazing and great. It was like one of my best experiences, like how difficult the professors that I’ve had in the past. I would say your class and you as a professor was my best professor who was understanding, yet challenging us to be that put out or best.

This seems to be the pattern for several students; they found enjoyment within the class because they found learning calculus is not as hard as they thought. Nikki’s comment supported the enjoyment as a result of collaboration when she noted, “I enjoyed it because you could talk to other people about the classwork. I believe that flipped learning allows students to get a better chance to learn about each other. Students will get comfortable with each other and make learning less difficult.”

Joe enjoyed the class because of the learning activities. He noted,
I actually really like that [flipped]designed because it made sure that people were really attentive and actively working on the problems that you’re giving us. For instance, I knew if there was a problem or I was having trouble, there was still the chance that you would call on me to like, ask me step-by-step of how to go through it. So, I think that motivated me to push myself to try and understand everything and do the work as and examples that you’re giving us, like as you were giving them to make me more efficient as a student.

Engaged in Learning

At the beginning of the semester, some students viewed mathematics as something meaningless because it seemed technical, disconnected, and drill or formula-like. In other words, they could not see an apparent reason for doing mathematics, and they needed the connections for clarity and understanding. Through active learning, I was able to engage students. It was great to hear students arguing, debating, and discussing mathematics in my classroom. They were engaged in the learning process.

Students shared how the flipped learning model promoted an engaging environment in the calculus classroom. For example, Mary said,

Active learning helped us to be engaged when we were actively participating in in-class discussions. Yeah, I thought that was pretty good. I really liked how if we ever had a question about something, you’d just put it up on the board and explained it to the whole class. There were obviously kids who are too shy to ask a question, they felt like their question wasn’t worth being asked, but there was still some kid that that was bold enough to ask that question. I really liked how you explained it for the entire class, probably clearing up for a lot of other students that didn’t ask the question.
The flipped classroom appears to have been a catalyst for engaging students. The questionnaire at the beginning of the semester demonstrated that students struggled with and feared mathematics. However, as the semester quickly progressed, the classroom was altering their preconceived notions about mathematics. I wrote in my journal,

Using The flipped learning model has increased interaction between the students and me while engaging students in the learning process. My focus is on the student’s learning and challenged them. They are more willing to show what they know instead of sitting in their seats, looking confused. Not to mention, they want to be engaged in problem-solving activities and discussions, which rarely happened before I flipped my classes. (February 23, 2020)

Students noted at the beginning of the semester survey that they faced challenges in learning mathematics/calculus. However, the flipped classroom as an effective mathematics classroom resembles a laboratory and engaged students in problem-solving and not just the manipulation of symbols. Slowly, over the semester, students began to realize that they could learn actively representing that data, identifying relationships, and expressing relationships symbolically. In turn, because of being engaged, students’ attitudes were changing. Students noted that the activities were engaging and helped to break the monotony of the traditional lecture class. Many students said they enjoyed the Calculus class because they were doing math.

Weeks Five and Six: Opportunity for Relearning and Benefits of Preparatory Work

To enhance the flipped classroom design, I looked for practical challenges and solutions reported in the literature. Some literature found that students’ median engagement time for an instructional video clip was only six minutes and reported that students might drop out if the
video takes longer (Jungic et al., 2015). With this finding in mind, I paid a fee and let my
students access more instructional and shorter duration videos. After this modification, there
were very few occasions when students came to class unprepared. Joe spoke about the videos
said, “I thought it was pretty helpful because all our lives we came into a math class and we
would just have to learn it, but now I am glad that I got to see it before I came into class.” When
I asked him if he re-watched portions of the videos, he said,

Yeah, like, I would be working on the homework and watching the previous video, the
one that goes over that section [in the homework], and if there was a problem that I had a
hard time understanding, I would go to where that is in the video and work through it
with that.

Ashely also mentioned,

In the videos, you presented some topic, and then a problem appeared. We could pause
the videos to solve the problem ourselves. We did that, and then we could see if our
solution was correct, sitting at home. It was nice.

Additionally, based on the fourth week’s CIQ comments, I modified the flipped classroom
by adding more pre-class assignments so that out-of-class time was highly structured and
prepared students for in-class activities. Students supported the argument of having the
opportunity of some pre-class assignments. One student said that the pre-
class assignments helped him to be prepared for the new topic in the following class session. He
said, “I liked how I could learn the material at my house and pause the video as frequently as I
wanted and regroup so I could make sure I understand the lesson.” Then he noted the videos
“established a baseline for discussion” in class the next day, so we know what to expect.
Additionally, I dedicated time to determine and assist with the difficulties that students had in processing the material. One of the most important issues raised was the participation of the quieter students. Some students liked to dominate class discussions. Although their contributions were welcome, sometimes it deterred the less confident students from participating. I understood that my role is an essential component of the active flipped classroom. During the class activities, I changed my role to a facilitator and directed my attention to the quieter and often weaker students. Ashley said, “It was helpful that you engaged us deeply. I felt comfortable enough to ask questions. Your flipped learning classroom also flipped my attitude in learning Calculus.”

I was able to make the flipped classroom a relaxed and encouraging classroom so that Mary said the following,

I felt I belong to the class, and it was because you were so understanding and supportive.

I liked this class, and I really wanted to come and listen and work with my group.

Something was clicking. The assignments, group work, and your support were enough to succeed. I can’t believe it, but I can say I learned calculus.

Students in the flipped class believed the activities done in the class led to increased learning opportunities. However, I understood pre-class activities are of limited value if students do not actually complete the work. The review of the literature indicated that monitoring students’ class preparation could be difficult because flipped instruction relies on video watching instead of doing paperwork (Clark, 2015). Therefore, I developed entrance quizzes at the beginning of each week by which I could monitor students’ endeavors and performance in their out-of-class learning.
Students appeared to be enjoying the flipped classroom more than previously. I gauged this by observing their behavior, administrating questionnaires, or conversation during or after the class. Students liked the activities, but they also contributed ideas for future activities. I created more activities. In addition, prior to class, the students gather requisite items for the forthcoming class meeting, often viewing lecture videos as part of the work done at home. Through literature, I found that some teachers choose to repeat the video lecture instead of in-class activities to enrich students’ learning experience (Clark, 2015). Instead, I employed small-group learning activities to engage students in a meaningful mathematical dialogue with the teacher and other students (Ichinose, 2014).

Aligned with engagement is the notion that the activities gave the students opportunities to work in groups; I noted within my researcher journal,

Students seemed actively engaged in their learning. Two student-participants that had previously sat at their desks without taking many notes and participated rarely were working with their peers without needing to be encouraged. Besides, three students who had not previously asked questions in class did so during today while I moved around the classroom, facilitating discussions. The small group discussion and collaboration may be less intimidating for students than whole-class discussions; thus, they may be more apt to ask questions. Engaging experience pertains to the effectiveness of the learners’ self-learning opportunities inside and outside of the classroom. These learning opportunities are allowing students to ask questions, express viewpoints, and make practical applications. (February 18, 2020)

**Benefits of Preparatory Work and Pre-class Assignments**

At the core of the flipped classroom is the necessity of completing pre-class activities.
The flipped classroom reverses the common classroom expectations, requiring students to prepare before a class session and then apply what was learned in class meetings.

Part of the preparatory work involves pre-class assignments. Students understood that without proper preparation, active learning could not occur in class. So, they appreciate the opportunity to have an additional source before learning the new topic. Most students liked best because they had a broad base of knowledge before class and improved overall understanding. For example, Zack stated, “I liked the opportunity to learn about a new topic twice, once at home, and then more in-depth at school.” Furthermore, he went on to say he also “likes the extra time to work on problems in class.” Other students supported the argument of having the opportunity of some pre-class assignments as well. Nick mentioned that the pre-class assignments helped him to be prepared for the new topic in the following class session. “I liked how I could learn the material at my house and pause the video as frequently as I wanted and regroup so I could make sure I understand the lesson.” Then he noted the videos “established a baseline for discussion” in class the next day, so we know what to expect.

Joe described this opportunity and said, “I liked it when we got our material beforehand, and then we just basically learn how to use it together.” Mary supported her argument when she stated, “with pre-class activities, I could see what skills I need for a certain topic. For example, for derivative or integral. Then I worked on those, and in the class, I understood better.” Nikki commented, “You know, I think that I personally enjoyed the outside-of-class structure of this class—I enjoyed coming in, knowing the material, feeling that I was on a level where I was able to communicate easily with the teacher.”

*Videos, Opportunity for Relearning*

During the semester, I monitored the action research by leading informal conversations
about the lessons with the student each day, seeking feedback regarding the accessibility of the presentations and other sources, length of presentation, and quality of presenters in the videos the students chose to watch for the introduction of new content. The instructional videos were used to introduce the students to the algebra and calculus contents. In addition to pre-class assignments, students mentioned that the videos triggered their interactions.

Ashely said,

In the videos, you presented some topic, and then a problem appeared. We could pause the videos to solve the problem ourselves. We did that, and then we could see if our solution was correct, sitting at home. It was nice.

Nick was another student who was optimistic about accessing videos, “I liked the videos, I needed to apply what I learned in the video, by solving problems. I needed to discuss and debate the problems with someone.” Fady added to this by expanding on ideas about the availability of information. He indicated: “Umm, so, I guess I feel like I learned more for a couple of reasons. Like I worked harder, but it was easier to work harder because I had more information available to me whenever I needed it.” Nikki later added,

I think that [the video being rewritable] definitely was a bonus but for me. It takes me a little bit. I can’t just like to listen to something and then know it. I think that’s definitely just being able to go back and relearn and rewatch helped me.

Overall, student support was overwhelmingly positive towards the preparatory work. They liked to know what is in their learning agenda for the next class and have some sources to go through and make themselves familiar with. Students noted their preference to have time in class to work on problems so they can ask questions. Joe commented, “in other classes, you learn the basics in class, and when you do the homework, you do not know how to solve the more difficult
problems.” Similarly, Nick stated, “We had more time to work on the problems which we did not understand.”

**Weeks Seven and Eight: Collaboration as a Key Factor**

For many STEM majors, Calculus is a primary course requirement; thus, it is critical to examine whether flipped learning can improve student achievement in this gateway course. Students began performing better in collaboration and group work. On the second week questionnaire, the students indicated their preference for a teacher-lecture pedagogy, but later in the fourth-week questionnaire and end of semester’s interviews, they explained that their initial apprehension toward the flipped classroom was caused by an unfamiliarity with the strategy and reported that by the end of the third week they had come to regard the flipped classroom more favorably.

I always attempted to engage the students in class and encourage them to collaborate and change their thoughts. Another journal entry also highlights group discussion when I noted,

I think collaboration really leads to some interesting discussions with students sharing personal experiences. Today, six groups working on finding error activity. I gave them an indeterminate problem contains two errors. Students in each group worked hard to find the error and earn extra credit. I see that working on the same assignment in class provides a learning environment in which students can share their personal experiences during collaboration and reach out to each other quite a bit to help each other out, so I am not the only person answering their questions. (February 28, 2020)

The students verified my observations that the flipped classroom model increased peer-to-peer collaboration and discussion. Joe stated, “I liked working together during flipped and felt more connected to people in the class.” Then he added, “while I benefited from my interactions
During the class activities, my role was changed to a facilitator, and I was able to direct my attention to these quieter and often weaker students. This helped me to gauge their understanding of the concepts we were covering. I also increased my office hours and gave extra credit to students who could help students who may be struggling with key concepts. The sixth week’s questionnaire also offered the student the opportunity to provide input in their own words about flipped learning and provided recommendations for improving the initial design.

The flipped classroom’s main effect was found in its use of class time to engage students in meaningful sense-making activities on difficult content. I also found that I needed to ensure I had additional reserve activities when students completed a task ahead of schedule.

At the beginning of the semester, when I asked what comes to mind when you hear the word math, some students had negative attitudes about their mathematics classes. They remembered a bunch of numbers and formulas that don’t make sense. They thought of math classes as harsh, abstract, and far away from joyful experiences. For many students, calculus was hard, and they did not see themselves as able to learn it. However, the flipped classroom seemed to alter the participants’ perceptions of calculus and their ability to learn. Slowly, over the semester, I observed students’ attitudes were improving for most parts. They discussed their learning process with each other and began seeing connections and applications of calculus. They even started to see connections between mathematics and other disciplines instead of mathematics as an abstract entity. Joe stated, “I liked working together during flipped and felt more connected to people in the class.” Then he added, “while I benefited from my interactions with you, I found interactions with my peers more beneficial.” Another student (Fady) referred to the collaboration component as:
The most effective component of the class. It’s like you get five or six teachers instead of just one. So, if you don’t get something the way one person explains it, we’re encouraged to collaborate and try other avenues until we get it.

The Mid-term questionnaire indicated that students realized that they could learn mathematics and their grades demonstrated that they could do it. Once their perceptions began to change, they become empowered and confident in their mathematical learning abilities. These connections were enhancing the students’ understanding and meaning of calculus and ultimately changing their attitudes. Students were able to see each other’s perspectives and how to integrate these concepts into their learning. Fady said,

I think that when we were able to work on problems in groups and share our ideas with our peers, that helps out a lot. Sometimes one person is stronger on a certain aspect and can help explain it better. Also, it’s a way to socialize with the students in our class and build a bond with them and maybe a friendship.

Collaboration in Flipped Classroom and Creates Community

The constructivist vision encourages the creation of learning environments that promote individual and group inquiry in which students’ informal knowledge is recognized and utilized. In such an environment, students are supposed to work primarily in collaboration with their peers on mathematical tasks (Kennedy, 2007). In the first eight weeks of class, collaboration within the flipped classroom created a community of math inquiry when we met face-to-face. Group work was an integral part of each class period as students were required to work collaboratively on the in-class learning activities. Students felt they had benefited from this aspect of the class and commented on the importance of collaboration to their learning.
Mary said, “collaboration was actually really good because we were able to learn from a student’s perspective. Students approach a problem differently, and it would be really helpful to see different approaches for one single question.” She also added, “I liked working together during the flipped and felt more connected to the people in the class.”

I see the relative reflection in my journal. I noted in my research journal,

Today’s class was very productive, and I think the students enjoyed it. After class, one of the female students commented and said she enjoyed class since I didn’t do any lectures and gave them some activities to do in a group with their peers. She said I believe this is more exciting to be able to break from the norm every once in a while. (January 23, 2020)

My main goal of using the flipped classroom model was to be able to have more classroom time for activities and collaboration rather than lecture. I wanted students to do more collaborative activities; I feel that once they have that background knowledge, that there can be more group and collaborative type activities, which help them to develop deeper mathematical understanding. As Ashley said,

I can say I learned more in this course when we did activities with our group. Like, when you gave us a question and asked us to do just one part and give it to other students in our group [roundtable], and then you would make someone go up on the board and do it when explaining. I liked other activities, but this one was my favorite.
Building Knowledge Through/ Learning from each other

Active learning and specifically flipped learning helped students to construct knowledge and learn from each other. I was able to perceive that flipped learning leads to increased content knowledge for students, not just by having lectures they can view and review, but because of the extra class time allowed for more guided practice and application in the classroom, which put that background knowledge to work. I noted in my researcher journal a month into the semester,

Today’s topic was about implicit differentiation as a challenging topic for many students, which usually creates some confusion. Many students didn’t understand why this derivative is different. I opened the discussion and tasked each group to lead the conversation and share it with the class. I was watching two groups debating about when we need implicit differentiation and how to find it. I liked the argument of one of the groups with a simple but thorough explanation. They explained that implicit differentiation is a technique that we use when a function is not in the form $y=f(x)$. It allows us to find the derivative of $y$ with respect to $x$ without solving the given equation for $y$. Then they looked at me and asked me for approval. (January 30, 2020)

This example illustrated how I attempted to engage the students in class with dialogue and discussion and how students can quickly learn from each other. Another journal entry also highlights group discussion when I noted,

In one particular group, a student asked a question. One of my good students attempted to answer the question, but an error was communicated during his explanation. I wanted to jump in, but I waited to see if they could figure it out. After a few discussions, they discovered the misinformation and clarified it themselves. It was a wonderful learning
experienced! It was no longer necessary for me to contribute to the conversation.

(February 4, 2020)

*The benefit of Discussion and Debate*

Group work “allows individuals to deny, criticize and justify concepts and facts, as well as find opposing views and generate a new perspective in social interaction or self-deliberation” (Rojas-Drummond & Zapata, 2004p. 543). Students appreciate the discussion and social learning aspects of the class. They stated that they most liked the group learning activities or working with their peers when we were at the campus, and our class was face-to-face. Joe said: “the one thing that I like most about the class would be the discussion and group work. Even after [class] hours, we came together as a class to work on the problems.” In a similar statement, Fady said, “[I most like] my peers and the way we worked together.”

Students perceived the benefits of discussion in the class. In other words, students perceived that both the person explaining the material and the person receiving the explanation benefited from the experience. It seems students are so helpful in facilitating dialogue and discussion between the group members. I noted in my researcher journal,

Students worked successfully in collaboration to complete their assignments during the class. They communicate about their mathematical thought processes and sharing learning strategies. A group was talking about the cases where a limit goes to infinity. One of the members was confused about the limit at infinity and horizontal asymptote. The groups were discussing different cases, and one of them was able to provide his own interpretation of this phenomenon and explained very well that limit at infinity is the long-term behavior of functions. This means what happens as x gets really big (positive
or negative). Sometimes the function will approach a specific number such as L, and sometimes it doesn’t. He also offered an example. (February 27, 2020)

The students verified my observations that the flipped classroom model increased peer-peer dialogue and debated. Mary stated, “I liked working together during flipped and felt more connected to people in the class,” and Nikki said, “I liked working together and would like to do active learning.” Student statements also indicated that students found discussion efforts to solve problems and master concepts beneficial to them. For instance, Fady expressed the opinion that “an individual student can make mistakes in [efforts toward] comprehension of concepts or in problem-solving, but a group of students is much less likely to [collectively] make the same errors.” Then he continued and said, “Yes, I felt a greater connection to my classmates as a result of using the group work sessions.”

**Dealing with Challenges of Group Work in the Face-to-Face Classroom**

The flipped calculus class format was not lecture-based, as were nearly all of the previous mathematics courses that the students had taken. Students spent the majority of class time working in small groups collaborating on problems posed by me. When we met face-to-face, group working was one of the most critical and well-received components of flipped learning. Students enjoyed working in small groups on problems posed during class. Nikki commented, “working in groups was beneficial as it provided very different perspectives when working through problems.”

While there was a positive endorsement of collaboration and group works, a few students also criticized group working. They complained that the group work was often unproductive when they were paired with peers who did not share their level of interest or motivation. Nick said,
I think it was sometimes harder to work with the other students because some would be way ahead, and some would be way behind, so you kind of had to find the people who had the same method, you know. Some peers were ahead of me; they already took calculus in high school and had enough knowledge and skill. They were able to finish the work when I was just the beginning. They won’t know what I’m talking about.

Zack also stated that he did not benefit from working with his group when he said, “group work was only occasionally beneficial, but not when people didn’t try. Sometimes working with people who don’t know or don’t care made group work unsuccessful.”

**Summary**

Initial data showed that students entering Calculus I have struggled to learn mathematics in the past. Data collected over the course of the semester showed that the flipped classroom appears as a catalyst for engaging students and changed the student’s initial perceptions about mathematics. As their perceptions were changing, the students' confidence in learning calculus increased, and they found learning in the flipped classroom to be more enjoyable than past experiences.

In general, students were satisfied with the collaboration. They agreed that the group activities pushed them for the “why” behind mathematics problems and were more conceptual than previous mathematics courses they had taken. Also, it helped them to be exposed to the different perspectives of mathematical concepts. The purpose of the different perspectives was to get students to think differently about mathematics.
CHAPTER 5

FINDINGS FROM THE VIRTUAL FLIPPED CLASSROOM

The purpose of this action research study is to explore how learners and the instructor experience learning Calculus one (Calculus I) when active learning is implemented in a face-to-face and virtual classroom.

Later on, due to the exceptional circumstances (COVID-19 pandemic) forced upon everyone, educational setting included, and making this study more meaningful, substantive, the same research questions were visited for virtual learning using Zoom video technology. The study continued to address the same questions under the new Zoom teaching and learning environment. Hence, the next three questions focused on the virtual classroom and Zoom video technology as the new environment. This is the subject of this chapter, which focuses more on the questions:

a. Does active learning promote a community of mathematical inquiry in a virtual college calculus classroom?

b. What is the perception of the instructor, as a researcher, concerning active learning in a student-centered virtual college calculus course?

c. What are the experiences and perceptions of students regarding how active learning techniques like flipped learning classroom affects their learning in a virtual classroom?
Planning and Action Phase for the Virtual Flipped Classroom

The study took place over 8-weeks face-to-face, and a 7-weeks virtual semester in the Calculus I class. After I began to collect data in early 2020, the novel coronavirus disrupted face-to-face sessions half-way through the course. As the situation became increasingly urgent in early March, the administration decided to cancel all face-to-face classes for the rest of the semester and asked students to finish their courses in constructed online versions. This was overwhelming for students and myself. The situation changed, and we were forced to use virtual classrooms at a moment’s notice. This was an unprecedented new instructional environment that was not used in the past, and now, it was needed to be created.

I should admit that this made me nervous. I had prepared and planned my research project for a face-to-face course, and I was so excited to do so. But COVID-19 has introduced a wide array of challenges, and I had to substantially change the way I had designed my course and my research to accommodate the synchronous new online format which was unfamiliar to my students and me. Online teaching is not novel and has existed for some time now. As a means to deliver classes, online instruction can accommodate various distances and different student schedules. What made online teaching delivery different in spring 2020 was that the students had not signed up for online classes. They had enrolled in a regular, commonly known Calculus I course. It was somewhat challenging to introduce them to a virtual flipped-classroom environment. Initially, 28 total students were registered for the course. However, just eight students consented for the end of the semester’s interview. The eight participants were freshmen, and the first time taking calculus in college. All participants were STEM majors. In the following sections, I explain how I was able to keep active learning in the remote classroom via Zoom. I also talk about students’ perceptions and challenges.
Weeks Nine, Ten, and Eleven: Getting Familiar with Zoom

Even though it was challenging, due to the flexibility of action research, I expanded my research into the effects of online synchronous instruction using the flipped classroom and comparing and contrasting what worked. I continued to collect data while switching to a Zoom classroom. This enabled me to understand how active learning works in a flipped course using Zoom technology to create a dynamic environment.

In the Zoom classroom, I kept writing up observations. My journal’s notes are evidence of an uncertain time for students and for me. At the beginning of virtual learning, we all were unsettled since we were not prepared for virtual teaching and learning. However, we gradually gained familiarity with and confidence in this form of class structure.

To enhance the Zoom classroom’s learning experience, I participated in a two-day-long online professional development training program sponsored by our mathematics department. The workshop included training activities to assist instructors in modifying a face-to-face class to a virtual class. This included: learning how to create lecture videos with different media, developing online activities, and identifying characteristics of higher-level questions to be used within the classroom activities. I specifically used this training to revise my flipped calculus class to a Zoom classroom.

I modified some active learning strategies to be used in a Zoom classroom. I provided fill-in-the-blank style notes to allow the students to focus on the given lecture, whether that was in a Zoom class or via video outside of class for the flipped class. I used WebAssign (an online instructional tool) to let students practice and do their homework. I used other online sources such as MyMathLab and Maple lab assignments. Canvas also played an important part. I used Piazza (a free platform for instructors to manage class Q&A efficiently) and Packback.
questions, an Inquiry-Based Online Discussion. Packback is an excellent feature offered through Canvas. It acts like a “Digital Teacher Assistance” to coach students to ask their own open-ended questions and auto-modera te the discussion. By using Packback, students were able to ask practical questions and get immediate feedback, responses, and arguments.

In addition to lecture videos, students had access to Zoom recordings. They were responsible for taking notes and understanding the examples demonstrated in the video lectures and Zoom recordings. Occasionally, students were required to create and film their own videos of working on the problems. The videos were submitted for my review and then were posted to Canvas for students’ review purposes. The solutions to the activity problems were posted the following day on Canvas.

Zoom’s Polling feature allowed me to put up simple multiple-choice polls. It was a quick, easy way to check the opinions or thought processes of my students when I posed a question. This feature helped me to engage and assess the students. Also, I kept using Minute papers, which provided students with opportunities to reflect on course content. Before my online session, I could write an open-ended prompt and asked students to respond to in less than three minutes. This active learning strategy simultaneously allowed me to quickly check my students’ knowledge.

*Zoom Recording*

In addition to the videos, I recorded my Zoom classes and made them available to students. In general, students reported being highly satisfied with using Zoom recordings. The students mentioned several reasons for this. One was the possibility to pause and rewind the recording. Fady said,
I took notes during lectures in Zoom and also watching the recording. During lectures, things moved too fast sometimes, so that I almost had to give up taking notes. With recording, it is nice to be able to write at your own speed and calculate at your own speed.

At the beginning of learning through Zoom, Mary had a significant technology issue. Later, she explained how the recording helped her to stay connected. She said,

Many times, my Internet connection was so bad, and I had to leave Zoom and return later. When I start wondering about something in the lecture, ‘Why did this happen’? I looked at notes that you posted before the class and also watched the recording, then I started figuring and calculating.

Ashley echoed this perception stating,

It helped me realize that I have more resources. I honestly thought in online learning, it was me and math textbooks that are not easy to understand. Now that I went through a semester, I realize that I had more resources because, with the flipped, you have that technology to go out and look up other ways to do things. It has helped me realize there is more out there to help me learn.

Nikki continued and commented,

I liked the video and zoom recording since I could replay sections that were confusing. I would do the video, and I would make sure that I understood the video. But it was nice to be like, ‘I didn’t catch those last three steps. Let’s watch it again. But it was very good that we also had a recording of each class. I wish you could record the breakout room as well.
Challenges for Group Working in the Virtual Classroom

Collaboration and group working changed in the virtual classroom. While some students believed they were able to collaborate and work in their group through Zoom, some others had concerns and issues. Fady thought remote teaching didn’t impact collaboration in the flipped class classroom. In considering the technological tools used in collaboration, Fady highlighted the variety of resources accessed by his and his classmates in stating:

We were able to communicate through the computer, so whether it was, you know, social media, or email, or um, at one point, we had the Facetime type stuff, or Skype, or whatever, so we could use that as much as we wanted. So, I think I definitely reached out a little bit more, you know, when I was at home to other students, you know, for help and stuff.

Nikki discussed this further, describing how she and her group promoted collaboration when she said,

We studied together and helped each other if we had a question with math, either with a website or homework. We did this before the pandemic too. So, if it was a question with WebAssign or like a homework problem that we didn’t understand, we would either FaceTime or try to explain it through text. So, I thought the collaboration was really good because sometimes students can explain it in a way that’s a different perspective on the problem.

Mary then discussed this idea further in terms of increased interactions that extended beyond the classroom setting when she said, “I think I interacted more with fellow students after COVID-19 crises a lot more rather than inside of school.” She also stated:
We collaborated virtually more because we would watch the videos and then work on the homework together over Zoom or Snapchat. We’d work on a problem and be like, hey, I got this. What did you get? Most of the time, we’d have different answers, and we’d all have to go back through and rework it and find out what the right answer was, so we’d do this one problem, and we’d do it like a few different ways, and then we’d like to talk it all out and find the right way to do it.

While Joe combined several of these concepts in stating: “If we wanted to work with our group, we could figure out how to do it, there are many tools out there to communicate, and we are all good at it. Like Twitter, Facetime, or texting.”

Even though students were happy and satisfied with their collaboration in virtual classrooms, I had a feeling that mathematical discourse among them noticeably decreased. When I reviewed my journal, I see that my notes indicated this concern. I wrote, “it doesn’t seem all students do their activities, and some are quiet and not interactive. Some students seem awkward in their group.” I was hoping to retain some level of normalcy in this very abnormal situation. I wanted to see students’ faces which it could be more conducive to a teaching environment that fosters collaboration. However, students have begun requesting the permission to turn their camera off during the class. This request was supported by university’s policy. Therefore, at the very least, I asked students to upload an actual picture of their face. It was better than seeing a blank page.

Positive and negative comments about mathematical discourse and engagement appeared in my journal during the last six weeks of the semester. I noted at the beginning of April,

While synchronous virtual classrooms provided me the ability to interact with students instantly and afford the students the chance to participate in group activities in the
breakout rooms, I have the feeling that students cannot have the opportunity of discussion as they had in face-to-face. Even though I have many students that work exceptionally well in groups and together, I noticed that some students are resistant and do not collaborate well when they are in breakout rooms. They said they prefer to sit quietly and complete the work on their own. (April 6, 2020)

A few students’ feedback confirmed these notes during the interview. For example, Zack indicated that group working was not working in a virtual classroom. He said, “I’m just speaking for me, but I think the weakest part of it [virtual classroom], was obviously by just doing group work.”

Ashley had a diverse perspective on collaboration in the virtual classroom. She said, “collaboration in an online class can be good or bad depending on the efforts made on the part of the students.” Then she iterated that students needed to put in the effort in group work for it to have value. “It is annoying working in groups without adequate background or preparation. I disliked being in groups with [group] members who contributed nothing.”

Nick’s concern was different. He said, “I think group work in Zoom environment worked well for me except the times that my connection was poor, I was kickoff the room, and when I returned, I was lost.” I struggled with the virtual group work as well, but for reasons different from the students. I indicated in my journal,

I struggle to understand whether the group work is truly productive in breakout rooms since the group, not me, control the learning of the group. I am unable to decide if learning is taking place. I have to have hope that students work together. I don’t want to assume that when I watch students, they collaborate, but I guess I feel more informed
when I am directing the learning. I think I have to trust that learning is occurring since students are doing well in their assignments, such as quizzes or tests. (April 9, 2020)

I tried to encourage students to communicate and collaborate, but it was a unique and unusual situation. We all worried about the health of ourselves and our loved ones. Some students panicked; they lost their job or their parents had been laid off. It was not easy to keep the same class environment that we had before the pandemic.

I realized today that I have been in denial in the past few weeks regarding online group work. I have numerous students that work exceptionally well in groups and together. However, I noticed some students are resistant and do not collaborate well. They have their own reasons such as internet issues, the right equipment, Zoom attacker, and so on. Since I have no visual contact with them, I can’t say anything, but to say managing the groups in a virtual classroom is a challenge for me as the instructor. I struggle with approving or disapproving of their excuses as well as motivating the unmotivated student. (April 29, 2020)

**Weeks Twelve, Thirteen, and Fourteen:**

**Teaching from Physical to Digital and Challenges in Virtual Classroom**

In the Zoom flipped classroom, learning calculus was also achieved by studying provided materials, watching videos or other online resources, and completing brief assessments before attending class or at the start of class. The majority of the time was also devoted to allowing students to assimilate their knowledge through structured group problem-solving activities, small group discussions, and whole-class discussions, all under my guidance. Zoom has some features such as whiteboard or breakout rooms by which I was able to keep students engaged. The in-class portion of the virtual flipped class often included small-group work (two
or three students) around a set of practice problems. While groups completed work, I moved to
different breakout rooms to observe student progress and interactions, answered questions if they
arose, and corrected students if errors were discovered in work or methods used to solve
problems, just as I would do in a face-to-face classroom. If I detected a common error or a
problem that seemed too difficult for multiple groups, I either provided a necessary step to
complete the problem or worked the problem with the class to a point where the students were
able to complete the problem individually or with their group.

My Teaching from Physical to Digital

My move from primarily face-to-face classes to 100% online teaching happened over a
hectic week in March 2020. My university announced Tuesday evening that the campus would
close for in-person classes until further notice, and the next Monday, I was teaching my first
completely online class using Zoom. I didn’t have enough time to prepare for such a profound
change as my mind was focused on so many different things, such as my health and my
family’s health. This concern was not exclusively for me. Students had the same concern or
even more. In addition to the problematic global situation, they were dealing with the loss of
school support networks, on-campus jobs, subsidized housing, work-study programs, and access
to technology. Many of them were struggling financially, academically, and emotionally as a
result of campus closures.

However, COVID-19 was a global issue, and nothing could be done except adaptation. I
spent hours learning how to make my flipped digital skills classes more interactive by using my
iPad, Apple pencil, different apps, and Zoom’s simultaneous desktop sharing, which allowed me
to assist students who were struggling more. My attempt was to create a relaxing environment
and maintain active learning strategies. This was HUGE.
I was worried and reluctant if I could do so. However, The first questionnaire response after the switch to Zoom was a relief and reduced my concern. Students spoke candidly about my teaching in Zoom and keeping them engaged in the virtual classroom. One student stated, I overall enjoyed Zoom teaching! I felt that it wasn’t so different than being in the classroom seeing as you were there able to teach us “in person” with your own examples and the ability to answer questions on the fly. I felt as if I was able to absorb the material the same way as if I were in the classroom learning. I also enjoyed the WebAssign on-the-go questions you had asked us because those are typically done on our own, and I have a more challenging time understanding complicated problems without any help.

Maintaining Active Learning in the Virtual Classroom

The open-ended online questionnaire was administrated in week fourteen. I asked students about their perception regarding active learning in a flipped virtual classroom, my ability to keep active learning in Zoom and my digital teaching in general, and what they thought of the challenges faced during online learning.

A student said, “the lesson format was much like how you were teaching at the campus, calling on people and trying to get them active. So, I feel you still were trying to get everyone to be more active even when we’re online. And so, I feel like you did a good job with that. Also, with WebAssign and doing online practice when we were in class, I felt like that definitely brought more active learning to the online setting, which was definitely helpful. Yeah, I thought it [online learning] transitioned really well, a lot better than other teachers. I felt just as engaged as before. I didn’t have any problems with that at all. I thought it was pretty good went through.

Then he went on to say,
So, the way I see it is that learning is learning. I don’t think it matters if it's online or on campus because it all comes down to how effective the teacher is teaching. So, I don’t think online is really a barrier to that.

Nikki was kind enough to compliment me when she said, “I’ve truly thought there are no tips because you genuinely did the best that you could give the circumstances of online. Yeah. I really have no other tips.”

The Zoom whiteboard feature helped me share my screen and write on my iPad as I did on the class whiteboard. Ashley liked it and stated,

Before the pandemic, in class, doing examples helped me a lot with the WebAssign and doing work outside of class, like doing different problems. And then after the pandemic, I feel like it’s like the same thing as, wow, you’re doing the problems on your screen helped me a lot. When we’re not in the class, I usually try to redo them without looking at the answer and then doing the WebAssign.

Joe added to this and said, “when you wrote on the whiteboard on Zoom, I could see it on my screen as you did it and then I could do it at the same time, so it was like you were there helping me with it, so I think it was very helpful.” Additionally, he stated, “I thought the blend between using the board to show us how to solve problems and having us do those types of problems on WebAssign right after worked really well.”

Zoom allowed me to keep active learning even after COVID-19 and switching to remote teaching. Just like a face-to-face classroom, Zoom allowed me to switch back and forth between different types of teaching methods such as lecture, small group discussion, concept map, error analysis, minute papers, and problem-solving. The interviewees compared their experiences of face-to-face versus Zoom flipped classes. They all acknowledged that there was more similarity
between the two teaching modalities. I kept uploading pre-class assignments and videos on Canvas. I recorded my lectures on Zoom and created activities to practice in Zoom breakout rooms. All of them helped students to be engaged as Mary explained:

That was helpful beyond the pandemic; you put more assignments through Canvas and asked us to review before coming to class. That, along with actually being able to open a recording section, class sessions, and being able to review exactly when we learned something, help me to stay connected and understand the materials.

**Perceived Challenges in the Virtual Classroom**

Each student was asked to give perceived challenges of the sudden change from face-to-face to zoom classroom and learning remotely. Many of these challenges were common among students. For example, Fady articulated his concern and said,

You know, when we were at the campus, we go to class and make sure to understand and then just go home and study. But after the pandemic, I guess just sitting in front of a screen for a couple of hours was pretty annoying, especially when it’s like, you know, tough material, but, hopefully, it won’t be the same in the fall fully.

According to students, socialization was another significant loss for online classes. Students mentioned losing the connection with other students, the faculty member, and the campus. When I asked them their preferences about learning modality, face-to-face or online, the majority of them preferred face-to-face with a flipped learning approach. Nick stated,

I liked your class, and I think your online class was pretty good too. But I definitely prefer face-to-face case like you got to see so many different people and your friends and
meet new people and walk around the campus and stuff like that. Definitely, face-to-face was much more fun and overall cooler experience.

Then he continued and said,

I think, after this, what I can take away is that I am not a social person. I’ve always been very anxious talking to new people, asking for help, all those things. I get terrified for raising my hand and having everyone look at me. But I think after this, I’ve been taking that for granted, the fact that I was able to sit next to other students and I can turn at any time and just talk to them. After switching to Zoom, I found myself alone again. I really missed that interaction.

Joe also missed the face-to-face class and described his feeling:

I was enjoying our class; I think everything was going well; I like flipped learning and activities that we did in class. I think you kept everything almost the same, but you know, it is not still the full experience. It’s just that it’s not the same when you get to go to class and stuff like that and work with others. I think it’s easier to ask in class.

**Zoom fatigue**

Due to remote teaching, Zoom had become part of our lives. It was the primary way to teach. The nature of Zoom as a videoconference took away all my non-verbal cues such as facial expressions, the tone and pitch of the voice, and body language. I had to work harder to interact with my students and pay more attention to technology rather than human. These consumed a lot of energy. Besides, teaching two classes back to back and two to three meetings after that made me anxious, exhausted, and Zoom fatigue. I wanted to help my students as best as I could, but sometimes I felt drained. However, I was not alone; students express the same concern throughout the interviews. Mary described her feeling as bellow,
I think the biggest challenge for me was back-to-back classes and just staring at the computer for such a long time without really any breaks. And only I had like many headaches. My eyes would hurt. So just staring at the computer screen, and I also thought this doesn’t really pertain to your class. But overall, I felt like I was doing a lot more than if we were in like in class just because teachers felt like giving more assignments to make up for the fact that we didn’t see each other. So, I thought some course load was more than usual.

Joe had a similar concern and said,

I had a feeling of utter hopelessness after having four classes back to back.

Sometimes throughout the conversation, my mind splits its attention between what people are saying and what’s happening on the screen. It’s definitely challenging, but I know there is not any better alternative, and I’m grateful for any chance to keep my classes running during these difficult times.

**Motivation and Distraction**

The bright sides of working from home saved a little time on the commute and maybe got a few more things done around the house. But these few good benefits cannot discount the online teaching’s challenges such as distraction- which had a significant effect on productivity. It was easy to get caught up in a Zoom meeting and forget to do simple things like turn off the camera when leaving the room for a moment. Students also described many of these challenges throughout interviews. Fady said,

We must pay attention as much as we can. I know it’s easy to kind of wander off or sitting at home, and just it’s very easy to get distracted. But try our best to stay on task
and stay motivated, like find something that motivates you. And that’ll help just kinda stay on track and just pay attention.

Tom experienced a similar situation and said,

I liked your class, and I didn’t miss even one class, but honestly, I am happy that we are at the end since I was afraid to lose my motivation to attend. In remote learning, the Zoom classroom was my bed, with a noisy background in our kitchen. My brother kept coming to my room. Who can be into it?

Then he continued,

When you are in a traditional way, so you are at the campus, and it’s easy to attend the course, but when you are home, you are watching TV, and you look at your watch and say, oh my god, it’s, you know, it’s time to go to the class. So maybe some students, you know, just say, oh, who cares, I’m gonna continue watching TV.

**Technology and Interruption**

Some of the technical issues common to Zoom contributed to the challenges that we faced during COVID-19. For instance, it was frustrating and exhausting to try to maintain a conversation while some participants’ Internet was slow so that audio can become out of sync or videos freeze. Or, some students forgot to mute themselves, which was distracting with background noise. In addition, it was so annoying that in the middle of the lecture, or group work, the video got blurry, sometimes blue, and often the faces were shaded and unrecognizable. It was even more aggravating when voices and images are frozen and broke up.

Sometimes in the middle of group exercise, we were interrupted. Most of the Interruptions were caused by the inadequate home setup of the students. These were a range of issues such as poor webcam functionality, low device battery, or audio problems.
Unforeseen Issues

When we met in a face-to-face classroom, I used a whiteboard whenever I asked the students to share their thinking and come to a group consensus about an idea. This was effective in eliciting students’ prior knowledge. After moving to the whiteboard in Zoom, I had access to a small board and a few pages. In order to say my point on a specific topic, I had to show everything on one page, which forced me to write small all around the page. Sometimes it got so disordered, and even I was confused. This was an issue for Mary that I didn’t know until I interviewed her and she said,

Sometimes I had a problem taking notes. You wrote everything on the board and all that kinda stuff like on your computer. I feel like that was kind of difficult to follow since there were many things on a very small page. Especially learning the new material that was that difficult.

Additionally, Tom’s issue was regarding taking the tests. He explained,

When it came to tests and quizzes, I always considered myself fairly good at taking tests and quizzes from just the perspective of managing time and like weeding out multiple-choice questions and that stuff. But when it transitioned to the online tests and quizzes, I found myself unable. It was much more difficult to manage time and make the most out of that, as well as unfamiliarity with that kind of test, taking a lot of the time was an issue. I think it’s gotten better as I guess a semester went on, but it’s still something that I would always prefer taking a test on pen and paper in front of me than taking the same test online. It is just not as easy, in my opinion, to do it online for various reasons.
Summary

Zoom classroom was the closest equivalent to the physical classroom that we could use during the pandemic. However, it was not yet a perfect replacement. When I am teaching in-person class, I can see students’ faces, notice non-verbal cues, and gauge their engagement level in real-time. Then, I can make adjustments in my lecture, their collaboration, group work, or even practicing in the class. During teaching virtually, all of these have vanished. However, I found the Zoom platform to be the easiest and more adaptable to my needs even though students face many difficulties, emotionally, financially, and academically.
CHAPTER 6
DISCUSSION AND IMPLICATIONS FOR PRACTICE

The purpose of this action research study is to explore how learners and the instructor experience learning Calculus One (Calculus I) when active learning is implemented in a face-to-face and virtual classroom. In this final chapter, I discuss how the data interpretations presented in chapters 4 and 5 are related to the study’s theoretical framework and the literature in which it is embedded. The remainder of the chapter provides implications and recommendations for future study and practice, followed by conclusions regarding the major insights from the research conducted. The chapter concludes with my personal reflections as the researcher. The results are discussed for each research question. The questions that provide the framework for the study and results are as follows:

1. Does active learning promote a community of mathematical inquiry in a face-to-face college calculus classroom?
2. What is the perception of the instructor, as a researcher, concerning active learning in a student-centered face-to-face college calculus course?
3. What are the experiences and perceptions of students regarding how active learning techniques like flipped learning classroom affects their learning?

The next three questions were added later on due to the exceptional circumstances (COVID-19 pandemic) forced upon everyone, educational setting included. To make this study more meaningful and substantive, the same questions were visited for virtual learning using Zoom video technology. The study continued to address the same questions under the new Zoom teaching and learning environment:
a. Does active learning promote a community of mathematical inquiry in a virtual college calculus classroom?

b. What is the perception of the instructor, as a researcher, concerning active learning in a student-centered virtual college calculus course?

c. What are the experiences and perceptions of students regarding how active learning techniques like flipped learning classroom affects their learning in a virtual classroom?

Since the last three questions were added after the COVID-19 pandemic, I provided a detailed narrative and explained the planning, action phase, and overall finding in two chapters. Chapter four explained the face-to-face flipped classroom while chapter five was about the planning, action phase, and overall finding for the virtual flipped classroom.

Essentially, this study searched for a new way to learn calculus for increasing learning and comprehension. There is a general problem to be solved in teaching and learning calculus. Since that problem involves students and their own learning environment, I used an action research methodology to solve teaching calculus practice problem. Action research allows the students involved in the course to be part of the problem identification and solution proposition. Through the action research model discussed by Kuhne and Quigley (1997), this study implemented a plan in the two weeks of the semester, observed what reactions and input the students had on the plan, reflected on the remainder of the semester with the students, and instituted another plan.

Through this action research, the students were part of the problem identification and solution proposition in both face-to-face and virtual classrooms. I revisited the study’s plan every two weeks and made some changes based on CIQ and students’ feedback. I revised the course
calendar a few times according to students’ input on issues regarding videos, pre-class assignments, homework, and group work.

**Constructivism and Flipped Classroom**

Recently, mathematics teaching methodologies became the main topic in educational reform in teaching mathematics through the many mathematicians and researchers’ efforts. Before the reform, mathematics was taught by behaviorist teaching methods in which the instructor was the sole information giver to passive students. In recent years many educators stressed a constructivist perspective on learning that is less focused on traditional behaviorist principles.

The constructs of constructivism have influenced the literature on adult learning (Merriam & Baumgartner, 2020). There are various forms of constructivism, but the framework used for this study focused on the tenet of constructivism that emphasizes the influence of active learning and social interaction in the learning process. In general, “constructivism derives from a philosophical position that we as human beings have no access to objective reality, that is, a reality independent of our way of knowing it” (Martin, 1994, p.1). Constructivism posits that learners construct their own knowledge from their experiences and make sense of those experiences (Glasersfeld, 1996; Merriam & Baumgartner, 2020). Based on this educational theory, students construct and reconstruct meaning by applying their background knowledge to new material.

Students constructed and reconstructed meaning in the flipped constructivist calculus classroom as they applied their background knowledge to new material. This process actively engaged all aspects of the mind to work together to synthesize incoming information (Vygotsky, 1962). In this study, students learned most efficiently with a base of pre-class activities and
organized schemas that could be used to build upon new information. The flipped classroom reverses the common classroom expectations, requiring students to prepare before a class session and then apply what was learned in class meetings. Students noted that one of the most critical components of the pre-class activity process was to stimulate reflective thinking while viewing the instructional materials. For example, Zack stated, “I liked the opportunity to learn about a new topic twice, once at home, and then more in-depth at school.” Furthermore, he went on to say he also “likes the extra time to work on problems in class.” He stated that just watching a video passively will not engage him enough to promote the intended deeper learning levels.

Students understood that without proper preparation, active learning could not occur in class. So, they appreciated the opportunity to have an additional source before learning the new topic. Most of what the students liked best was having a broad base of knowledge before class, practicing and asking specific questions and working with one another in class, and an improved understanding overall. They see the pre-class activities as an opportunity to learn about a new topic twice, once at home and then more in-depth at school. There were several quotes in both chapters that support these findings.

Constructivist approaches support providing a foundation of content to build upon through learning experiences and socially engaging students through active learning strategies inside the flipped classroom. According to Vygotsky’s Zone of Proximal Development (ZPD) (Vygotsky, 1978), there is a limit to what students can learn individually. The collaborative and social learning nature of the flipped classroom learning helped students to learn better. Recall Nikki’s comment and excitement about the increased collaboration from chapter four, where she said the following:
I think collaboration is what gets us excited about math. It’s more interesting when you can work on real issues with real people and with each other. We might still be solving the formulas ourselves, but the collaboration makes our work more meaningful.

Although meaning took place through social interaction and collaboration, learning was internally controlled by the learner (Powell & Kalina, 2009). Mathematics is a widespread and highly structured social activity, and its aims, goals, purposes, rationales, and so on need to be related to social groups and society in general (Ernest, 1999). Powell and Kalina (2009) asserted that “teachers and students must communicate to convey information and for learning to take place” (p. 247). This is true in this study since it was noticeable that students engaged in communication and continued practicing to incorporate the ideas that make sense to them and explain what they learned with other students when we met face-to-face. Again, these findings were supported in the quotes from students in chapter four and from my journal notes.

The students verified my observations that the flipped classroom model increased peer-peer dialogue and debated on mathematics problems. Student statements also indicated that students found discussion efforts to solve problems and master concepts beneficial to them. For instance, Fady expressed the opinion that “an individual student can make mistakes in [efforts toward] comprehension of concepts or in problem-solving, but a group of students is much less likely to [collectively] make the same errors.” Then he continued and said, “Yes, I felt a greater connection to my classmates as a result of using the group work sessions.” Additionally, during the interviews, most participants indicated that articulation is an active process that helped them think critically about the content and organize the information to be presented to others (Powell & Kalina, 2009).
This study showed that social interaction is a critical component of learning mathematics when students become involved and motivated in a mathematical community of practice. I always attempted to engage the students in class with dialogue and discussion. This is one of the best ways to learn mathematics. I was genuinely impressed with the conversation and debate occurring within the classroom. It does not seem like anyone is afraid to speak, ask questions, disagree, clarify, and explain. This is a point that I noted in my journal.

Weimer (2013) argues that within a learner-centered environment, the focus is placed on the learning by helping the student construct new knowledge based on such aspects as previous experiences and knowledge. As a learner-center environment, the flipped classroom empowered the students and transformed the classroom from a teaching environment to a learning environment. In this environment, students took responsibility for their learning. They were required to take on new learning roles and responsibilities beyond merely taking notes, listening to teachers speak, and passing exams. “It was an environment that allows students to take some real control over their educational experience and encourages them to make important choices about what and how they will learn” (Doyle, 2008, p. xv). The sections that follow integrate constructivism within the findings of the study. The discussion is framed around active constructivist learning and engaging in active dialogue.

**Constructivist Active Learning**

The active learning in the flipped classroom is supported by constructivism. Students had the opportunity to adapt and organize their own learning through double exposure and time to reflect on their learning in class. This includes collaboratively learning with others and time in class for knowledge to be actively created. Learning became an active process in the flipped
classroom rather than a passive one, as knowledge is constructed rather than innate or passively absorbed (Prince, 2004). Again, the many quotes from the prior chapters exemplify this.

As a result, in collaborative learning, I’ve become more of a facilitator and let students make those discoveries independently. In an active learning environment, students can better work at their own pace and master the content at a pace that is beneficial for them. Students take control of their learning, and in such an environment, as I noted in my journal, my role was to guide them.

As I changed my teaching methodologies to a constructivist active learning pedagogy and worked to create a supportive atmosphere where students felt safe to explore mathematical concepts, students were willing to become personally responsible for their learning, which positively affected their learning of calculus. When students were actively engaged, they became aware of their own errors and misconceptions. In this study, active learning opportunities, including instructional strategies with collaboration and learner-centered instruction, have been shown to affect two main factors that correlate with positive gains in student learning: (a) knowledge construction; and (b) student engagement (Prince, 2004). The process of active learning provided students with an opportunity to engage in active, critical, and collaborative thinking. This form of learning created excitement in the classroom that engaged students in doing rather than just listening.

Students’ beliefs about their abilities often emerge from prior learning experiences in which they failed or succeeded. At the beginning of the semester, the questionnaire indicated that students’ attitudes towards learning mathematics had been impacted primarily because the content of previous math classes did not prepare them for the class they were taking or because they had a bad memory of an incident in a previous math class. For example, one student said, “I
can get frustrated sometimes, and I just wish I was smart enough to understand.” Or another response was, “When I’m stuck... I feel like I have failed.” However, one of the best ways to help students develop a positive sense of self-efficacy is to have them actively engage in the learning process. This can be accomplished with the use of active learning strategies such as flipped learning. The learning process in the flipped classroom helped students to regain confidence. They learned how new knowledge is constructed by transforming, organizing, and reorganizing previous knowledge. According to constructivism ideas, learning is an active process through these processes, and knowledge is constructed rather than innate or passively absorbed (Powell & Kalina, 2009).

**Engaging in Active Dialogue**

According to social constructivism, knowledge is a human product, which is socially and culturally constructed actively and not something which can be discovered (Gredler, 1997; Ernest, 1999), and learning occurs through participation in a social environment with other students and the teacher (Cobb, 1996; Liu & Matthews, 2005; Powell & Kalina, 2009). In this study, active dialogue involved students dialoguing with each other and with the instructor. Their beliefs, assumptions, attitudes, and perspectives were challenged and examined in the community where the dialogue was encouraged (Fosnot & Perry, 2005). Joe stated, “group learning activities were the best part of the flipped classroom and helped me a lot to understand calculus.” Also, Mary mentioned, “the one thing that I like most about the class would be the group work and learning from each other.”

Students indicated that they felt responsible for learning as valuable contributors to the learning process. My journal indicated that students were engaged when working together. One student’s comment reflecting this was, “I think that learning with others is very helpful. More
than likely, they made the same mistake as you at some point and have figured it out and can explain it to you from their point of view, or you can work together to figure it out.”

The activities provided the students with an opportunity to be engaged with one another and with me in many ways. As a result of the group activities, there were numerous opportunities for me to interact with the students and engage in different immediacy forms with the students. Students engaged with the content related to their previous experiences and made meaning of the content as they grow their understanding collaboratively as a community of learners that interact and negotiate with one another as I played guiding role.

The sections that follow integrate the results for each research question. The discussion is around The Community of Mathematical Inquiry and Flipped Classroom, My Role as an Active Facilitator, Promoting Mathematics Learning Through Flipped Learning, Perceptions of Students Regarding Active Learning techniques, Flipped Learning in Face-to-Face Classroom, and Virtual Flipped Classroom.

**Learning Mathematics Through Flipped Learning**

Effective calculus instruction can transform instructional practices by facilitating students learning through active learning experiences and engagement of students in their learning (PCAST, 2012). Some mathematics instructors have suggested that the flipped classroom approach has the potential to improve mathematics instruction (Ford, 2015; Ichinose & Clinkenbeard, 2016). The flipped calculus classroom allowed me to develop hands-on activities addressing specific content that students were struggling with or concepts that were necessary for achieving particular outcomes. Tucker (2012) argued that hands-on activities not only allow instructors to see where students are struggling but also stimulate students and encourage engagement with course content, requiring them to do something with course content rather than merely memorizing it. Tucker
(2012) recommended various activities for student engagement, such as working on the blackboard, concept mapping, and jigsaw, debating, and playing games. Other examples of hands-on activities are writing in journals, speed challenges, and puzzles (Ichinose & Clinkenbeard, 2016). In flipped calculus, I created many activities and engaged students in their learning. Engaging experience pertained to the effectiveness of the students’ self-learning opportunities inside and outside of the classroom. These learning opportunities were allowing students to ask questions, express viewpoints, and make practical applications.

The National Council of Teachers of Mathematics (NCTM, 2000) recommended changing traditional methods to an approach that utilizes active learning by “using a constructivist method of teaching, in which learners develop meaning based on experience and inquiry” (White-Clark et al., 2008, p. 41). Like most other flipped mathematics classroom research (Petrillo, 2016; Seymour, 2006; Sonnert et al., 2015), the flipped calculus classroom changed my interaction with students by changing my role of the teacher to a facilitator. Rosenthal (2015) expressed that most mathematicians agree that the best way to learn mathematics is by actively doing mathematics, by discussing it with others, and by synthesizing significant ideas. Students need to do activities where they experience calculus and are really doing it. I encouraged group work as students were required to work collaboratively on the in-class learning activities. Students felt they had benefited from this aspect of the class and commented on the importance of collaboration to their learning.

In this study, active learning improved mathematics performance by building problem-solving abilities and critical thinking skills (Freeman et al., 2014; PCAST, 2012). It provided experiences for students to become aware of their errors and misconceptions, created activities, and gave students the chance to gain control of the concepts, encouraged student autonomy, and
helped them make useful and appropriate connections (Freeman et al., 2014; Petrillo, 2016). Active learning and specifically flipped learning helped students to construct knowledge and learn from each other. I was able to perceive that flipped learning leads to increased content knowledge for students, not just by having lectures they can view and review, but because of the extra class time allowed for more guided practice and application in the classroom, which put that background knowledge to work.

Research indicates that the learning environment, including pedagogy and student experience, can affect calculus achievement, persistence, confidence, interest, and enjoyment in mathematics and STEM education (Bhagat, Chang, & Chang, 2016; Bressoud et al., 2015; Petrillo, 2016; Rasmussen & Ellis, 2013; Seymour, 2006; Sonnert et al., 2015). In the learner-centered calculus classroom, “students develop their sense of mathematics – and thus how they use mathematics – from their experiences with mathematics (largely in the classroom)” (Schoenfeld, 2016, p. 7). In this study, learner-centered teaching gave the student an opportunity to practice communicating mathematical ideas. They learned mathematics by doing mathematics; they were an active part of the acquisition of their own mathematical knowledge (Bhagat et al., 2016).

Flipped learning helped in creating effective learning and allowed students to exchange resources, question each other’s conclusions, and defend their own ideas, which required students to use higher-ordered thinking (Schoenfeld, 2016). In contrast to the traditional classroom experience, in the flipped calculus classroom, “students were calculating, gesturing, arguing, helping each other, teaching each other, and most importantly learning (Jungic et al., 2015). As Bergmann and Sams (2012) stated, the one unifying characteristic of all flipped
classrooms is the desire to redirect the attention in a classroom away from the teacher and onto the learners and the learning.

One of the fundamental components of the flipped calculus classroom was that class time was reserved for the more essential aspects of learning, where students could interact about underlying concepts and applications (Abeysekera & Dawson, 2015). Bergmann and Sams (2012) describe the flipped classroom in this manner, “the one unifying characteristic of all flipped classrooms is the desire to redirect the attention in a classroom away from the teacher and onto the learners and the learning” (p.96). The flipped calculus learning provided more opportunities than simple lectures for students to work with me on difficult concepts and to improve their understanding of core concepts (Tucker, 2012).

According to social constructivism, knowledge is a human product, which is socially and culturally constructed in an active manner and not something which can be discovered (Gredler, 1997; Ernest, 1999), and learning occurs through participation in a social environment with other students and the teacher (Liu & Matthews, 2005; Powell & Kalina, 2009). In the flipped calculus classroom, while students engaged in communication, they were continually working to incorporate the ideas and make sense of them as well as convince others of their point of view. Additionally, articulation was an active process of knowledge construction because it demanded that the learner think critically about the content and organize the information so it can be presented to others (Powell & Kalina, 2009).

This study indicated that social interactions could promote learning (Vygotsky, 1978) even in a mathematics classroom. In this study, as students became more experienced with flipped learning, they voiced increased comfort with the idea of collaboration and were, in fact, ready to redefine their view of who an expert was, including recognizing peer and community interactions
as valuable to their learning. In addition to the use of videos and pre-class assignments, technology presented an opportunity to teach mastery level material. Students were able to extend their learning outside of class through their collaborative efforts with each other (Abeysekera & Dawson, 2015). The intentional resources and challenging, authentic activities allowed students to wrestle with information in different ways, which increased their awareness of which learning strategies and resources best supported the learning objectives (Abeysekera & Dawson, 2015; Schoenfeld, 2016). Findings from this study aligned with those of previous studies on mathematics, because the same result occurred and participants listed improved interaction with me as a benefit of the flipped classroom. They indicated that they experienced increased collaboration with other students. They also noted that the flipped learning created a classroom centered more on student responsibility for learning (Bergmann & Sams, 2012; Chen et al., 2016; Clark, 2013; Ziegelmeier & Topaz, 2015). My journal notes and questionnaire responses yielded evidence that the flipped classroom improved student engagement with the content through collaborative exercises and problem-solving in class (Clark, 2013; Ziegelmeier & Topaz, 2015). I also observed that students improved in their mathematical discourse as a result of the collaborative classroom activities in which they had to explain their thought processes and justify their choices to their peers (Clark, 2013).

**The Community of Mathematical Inquiry and Flipped Classroom**

The constructivist vision encourages creating learning environments that promote individual and group inquiry in which students’ informal knowledge is recognized and utilized. In such an environment, students are supposed to work primarily in collaboration with their peers on mathematical tasks (Kennedy, 2007). A community of mathematical inquiry is a model of this environment that encourages dialogue and discussion among students (Goos, 2004). A flipped
classroom supports the community of mathematical inquiry as an environment that allows talking about how mathematics learning entails communication in social contexts (Cross, 2009; Goos, 2004). From this perspective, mathematics teaching and learning are viewed as social and communicative activities that require the formation of a classroom where enacts practice (Lave & Wenger, 1991). According to this study’s data, the flipped classroom helped to promote a community of mathematics inquiry in which mathematics teaching and learning are viewed as social and communicative activities.

In the flipped calculus classroom, as a community of practice, students learned to speak and act mathematically by participating in discussions and solving new or unfamiliar problems. In this community, the value was placed on “practices such as discussion and collaboration...valued in building a climate of intellectual challenge” (Goos, 2004, p. 259). One of the main objectives was that knowledge could not be constructed through transmission or individual reflection and debate. It was through sharing ideas and synthesizing each other’s thoughts through distributed thinking in a dialogical context (Kennedy, 2009).

The data indicates that in the flipped classroom, students were able to create a community of learning by “questioning, offering examples, and counter-examples, asking for justification, giving reasons, offering clarifications, making propositional statements, exploring alternative positions and hypotheses, drawing conclusions, reasoning syllogistically, making inferences, and many others” (Kennedy, 2009, p.73). Students took ownership, increased their responsibility in their learning, and felt that explaining and justifying their ideas helped them understand mathematics (Goos, 2004). For example, Nikki said:

Watching all the groups present their solutions to the given problems and working on our own really helped me understand the challenging topics. I believe that sometimes people
learn a little better in groups. That way, they work with their peers, and everyone shares information on the parts that they understand better.

Students learned more in this course when they did activities in the group. As Joe said, “I liked working together during flipped and felt more connected to people in the class.” Then he added, “while I benefited from my interactions with you, I found interactions with my peers more beneficial.” This change is evident in that students felt that they relate to each other, to the classroom power and authority base, and to the discipline of mathematics itself (Cornelius & Herrenkohl, 2004).

In the community of mathematical inquiry, my role was challenged. I was not an unquestionable authority anymore, but I was a facilitator who “encourages the scaffolding process without providing direct answers or authoritative perspectives” (Kennedy, 2009, p. 75) and lets students make those discoveries on their own.

In instances where students were working together, the learning was in their hands, and they were learning from one another. The literature states that teachers should be “…armed with opportunity-to-learn strategies and facilitate students’ taking responsibility for their own learning” (Mid-Continent Research for Education and Learning, 2002, p. 7). In essence, a calculus classroom should resemble a lab. Most calculus classrooms do not look like this, but the intent is to create a classroom that does. This will require some change, but Calculus is the study of change.

**My Role as an Active Facilitator**

One of constructivism’s essential attributes is reframing the role teachers play in the higher education classroom (Barr & Tagg, 1995). Also, becoming a facilitator of learning is an
essential part of a learner-centered classroom. Relatedly, those who facilitate learning have been compared with coaches. Barr and Tagg (1995) write:

A coach not only instructs football players . . . but also designs football practices and the game plan; he participates in the game itself by sending in plays and making other decisions. The new faculty roles go a step further; however, in that faculty design the game plans and create new and better ‘games,’ ones that generate more and better learning. (p. 24)

In the flipped classroom, my role was to “facilitate and negotiate meaning-making with the learner” (Merriam et al., 2007, p. 295) concerning calculus and students learn to construct knowledge. I facilitated this active dialogue by building community, designing participatory activities, and soliciting students’ feedback regarding instructional practices. I frequently communicated to my students and while they were working on their learning activity, I circulated and offered my assistance. Students indicated that I helped them in developing relationships with each other. Nikki commented, “working in groups was beneficial as it provided very different perspectives when working through problems.”

Interestingly, while my role changed from teaching students to helping them learn, students could enhance their learning by becoming self-directed learners, learning collaboratively with their peers, and seeking assistance and guidance from me as needed. The flipped classroom changed the nature of my interaction with students. In a lecture class, I rarely had the chance to listen to the students as they developed their solutions to problems. In the flipped class, I more frequently got to watch the students at work. This allowed me to understand students’ misconceptions and respond to them promptly.
According to the students, the flipped classroom provided them with a comfort level with the material, with each other and me. Given the nature of a student-centered classroom, I was able to identify students struggling with understanding concepts and provide the support necessary for success. Students’ statements in the prior chapters support the premise that a flipped-classroom approach was helpful for students. It helped them stay focused during a long day at school and pay attention instead of being bored. They can reflect on their learning to integrate their new knowledge into existing schemas. Additionally, students were encouraged to actively think and solve the problem with the teacher as a guide. This changing role from the “sage on the stage” to a facilitative or coach role as a “guide on the side” did not reduce my responsibilities or tasks but rather required a realignment of roles (Weimer 2013).

Perceptions of Students Regarding Active Learning Techniques:

Flipped Learning in Face-to-Face Classroom

According to the literature, active learning has been shown to improve mathematics performance by building problems, solving abilities, and critical thinking skills (Freeman et al., 2014; PCAST, 2012). This form of learning provides experiences for students to become aware of their own errors and misconceptions, create activities, give students the chance to control the concepts, encourage student autonomy, and help them make useful and appropriate connections (Freeman et al., 2014).

In the present study, students had an overall complementary view of the flipped classroom. These findings complement a study done by Talbert (2014) in which he suggested that a positive perception of the flipped classroom improves students’ overall performance in the class. Data showed that students were interested in a more active classroom and felt like class
devoted to active engagement with numerous activities rather than passive listening and copying notes.

Nikki noted during her interview that the flipped class was better because “it wasn’t just sitting there lecturing the whole time being bored. It was more hands-on.” Participants reported that they liked the course structure, appreciating the ability to watch lectures on their own time, which is a characteristic of being student-centered. They also noted the ability for time management because of the time gained for working practice collaboratively and asking questions in their group. They also liked the benefits of the videos and resources and the enhanced understanding that they gained through the double exposure to content that provided scaffolding from working more simple types of problems to more cognitively demanding applications. Zack stated, “I liked the opportunity to learn about a new topic twice, once at home, and then more in-depth at school.” In addition, students supported the argument of having the opportunity of some pre-class assignments as well. Nick mentioned that the preparatory assignments helped him to be prepared for the new topic in the following class session.

Research indicates that the learning environment including pedagogy and student experience can affect calculus achievement, persistence, confidence, interest, and enjoyment in mathematics and STEM education (Bhagat, Chang, & Chang, 2016; Bressoud et al., 2015; Petrillo, 2016; Rasmussen & Ellis, 2013; Seymour, 2006; Sonnert et al., 2015). In a learner-centered classroom, “students develop their sense of mathematics – and thus how they use mathematics – from their experiences with mathematics (largely in the classroom)” (Schoenfeld, 2016, p. 7). In this study, an organized learner-centered classroom was another component that was supported by students. In the flipped classroom, I maximized the implementation of a
communicative, student-centered learning environment by which I could move beyond the lecture as the primary way that I used to deliver information and structure class time. It allowed me to introduce new ways of doing things and focus on other ways to enhance learning by introducing active learning strategies that put students in the center of the learning experience. It shifted my class from a teacher-centered learning environment to a learner-centered learning environment and from individual to collaborative strategies. Students acknowledged my ability to facilitate the discussions, provide feedback, and organize activities and applications. Given the nature of a student-centered classroom, I was able to identify students struggling with understanding concepts and provide the support necessary for success.

Learner-centered teaching approaches like flipped learning help create effective learning and allow students to exchange resources, question each other’s conclusions, and defend their own ideas, which requires students to use higher-ordered thinking (Schoenfeld, 2016). Although organizing the classroom and improving the working environment was a bit chaotic and took too much of my time, it allowed students to complete their work at their own time and pace.

In contrast to the traditional classroom experience, in a flipped classroom, “students are calculating, gesturing, arguing, helping each other, teaching each other, and most importantly learning” (Jungic et al., 2015, p. 512). In this study, students retained more information doing it this way. Instead of trying to rush and take notes in class, they stayed focused during a long day at school and paid attention instead of being bored. I always reminded students that no idea is stupid, and no question is dumb. It is each student’s job to explain to others if they understand or ask questions to clarify if they do not.
Increase in Mathematical Discourse

The flipped classroom is more efficient than the traditional classroom as valuable class time is not devoted to students attempting to follow the lecture, transfer notes from the board to their notebook, and apply the newly presented information (Bergmann & Sams, 2012). More importantly, the flexible characteristic of the flipped classroom creates a student-centered learning environment in which students must recognize and demonstrate self-regulated learning skills to succeed (Talbert, 2014). Every minute of the class was utilized for the students to engage in active learning. I was able to create a more accurate representation of what students know and do not know and where potential misunderstandings may be occurring due to the increased opportunity to communicate with all students in the class. I integrated and utilized a variety of in-class activities to enable students to utilize and apply information learned in the video lectures (Bergmann & Sams, 2012; Talbert, 2014).

Other mathematics instructors have suggested that the flipped classroom has the potential to improve mathematics instruction (Ford, 2015; Ichinose & Clinkenbeard, 2016; McBride, 2015). My data indicated that mathematical discourse among students noticeably increased. Before this, notes in the reflective journal specified some collaborative groups “were quiet and not interactive,” and “some students seem awkward in their group.” However, after a short while, when students became more used to the classroom environment, the increased engagement and mathematical discourse were noticeable.

In face-to-face flipped classrooms, students seemed actively engaged in their learning. At the beginning of the semester, some students viewed mathematics as meaningless because it seemed technical, disconnected, and drill or formula-like. In other words, they could not see an apparent reason for doing mathematics, and they needed the connections for clarity
and understanding. Their view changed through active learning, and they found enough confidence to argue, discuss, and debate mathematics. I noted in my journal: “I was worried about two students who had previously sat in their desks without taking many notes and participated rarely. But I see they are working with their peers without needing to be encouraged.” Following McGivney-Burelle and Xue (2013) suggested using an entrance quiz, I asked students to take an entrance quiz every Tuesday, which held students accountable and motivated to watch their videos prior to class.

The flipped classroom appears to have been a catalyst for engaging students. The questionnaire at the beginning of the semester demonstrated that students struggled with and feared mathematics. However, as the semester quickly progressed, the classroom seemed to be altering their preconceived notions about mathematics. I wrote in my journal,

Using the flipped learning model has increased interaction between the students and me while engaging students in the learning process. My focus is on the student’s learning and challenged them. They are more willing to show what they know instead of sitting in their seats, looking confused. Not to mention, they want to be engaged in problem-solving activities and discussions, which rarely happened before I flipped my classes. (February 23, 2020)

Students noted at the beginning of the semester questionnaire that they had typically challenging learning experiences in mathematics/calculus. However, the flipped classroom as an effective mathematics classroom resembled a laboratory and engaged students in problem-solving and not just manipulating symbols. Over the semester, slowly, students began to realize that they could learn actively representing that data, identifying relationships, and expressing relationships symbolically. In turn, because of being engaged, students indicated
their attitudes were changing. They noted that the activities were engaging and helped to break the monotony of the traditional lecture class. Many students said they enjoyed the calculus class because they were actually doing math.

Another perceived benefit pointed out by interviewees was how working in groups in class played a part in student achievement. For example, each of the interviewees described the experience of being in a group where the members would want to divide problems up, completing a few problems rather than doing the entire homework. This helped students work through problems that they would have encountered while doing homework independently, allowing them to develop problem-solving skills through collaboration. Students expressed that they liked group experiences since everyone was really responsible and really put in the effort. Having the ability to work at one’s own pace was something that the literature mentioned as a benefit to how the flipped classes are structured. This was an aspect supported by the interviewees. While class time was spent on assigned problems, any unfinished work would be completed at home. The participants adjusted to the reality that working in groups on problems often meant that the problems would be completed at a slower pace. Still, it was a fair trade to verify that each group member felt confident with the work that they were turning in.

**Online Zoom Classroom and Virtual Flipped Classroom**

In Spring 2020, the COVID-19 pandemic was overwhelming the functioning and outcomes of education systems when higher education institutions engaged in a rapid and unprecedented movement to remote teaching and learning. For the rest of the spring semester, I had to teach remotely and connected with my students only via Zoom. The result of the end of the semester’s questionnaires illustrated the students’ general beliefs about learning in a Zoom classroom and maintaining active learning in the flipped calculus classroom after switching to
remote teaching. Students expressed a different attitude, but mostly positive regarding active learning in the virtual classroom. In the following section, I’ll elaborate on the flipped Zoom classroom during the novel coronavirus caused a shift to learning from home.

**Social Constructivism in Online Spaces**

In Zoom classroom, the physical absence of the interaction caused the need for other ways to create the motivational link. Even though facilitating an online class was different from facilitating a face-to-face one, this study supports social constructivism in a virtual classroom. Human beings build their knowledge by integrating what they already know with the activities, ideas, and events with which they come into contact (Liu & Matthews, 2005; Powell & Kalina, 2009). Knowledge cannot be transmitted from one person to another. It is constructed in the human mind, either individually or in response to interaction and discussion with others (Powell & Kalina, 2009). In general, virtual classrooms supported the nine principles of learning to which most social constructivists subscribe. According to Epstein (2002), these principles can be guidelines for teaching and learning and are included: learning should be active, students have to learn how to learn, kinesthetic learning experiences and problem-solving enhance learning, language affects learning, social activity produces meaningful learning experiences, students need contextual information, and conceptual information to learn, learning takes time, and motivation to learn is essential.

Through social constructivism, teaching mathematics is a widespread and highly structured social activity, and its aims, goals, purposes, rationales, and so on need to be related to social groups and society in general (Ernest, 1999). While individuals engaged in communication, they are continually working to incorporate the ideas and make sense of them as well as convince others of their point of view. Constructivist learning is influenced by cultural and social factors
(Liu & Matthews, 2005). In other words, social interaction has a vital role in the student’s ability to create his or her knowledge (Schunk, 2008). In this study, students were able to communicate through the computer, social media, email, Facetime, or Skype. However, as Ashley said during the interview, “collaboration in an online class can be good or bad depending on the efforts made on the part of the students.”

Social presence is defined as “the ability of participants in the Community of Inquiry to project their personal characteristics into the community, thereby presenting themselves to the other participants as real people” (Garrison, Andrews & Archer, 1999, p.89). Zoom classroom helped to develop a community of learners in which students fostered sharing and collaboration through discourse. In this study, students created an online community that was functional, time-driven, and professional. Shared frustration and confusion might have been the incentive for building a community, but I believe the glue that will hold this community together came from the shared ultimate goal of successful completion of the course. Through online social interaction, students could build connections and trust in an online community.

Active online learning implies that learning in a virtual environment can be a dynamic process whereby students are participating in constructivist learning. Vygotsky (1978) emphasized the importance of the impact of environments on human behavior, development, thinking, and learning (Vygotsky, 1978). In the virtual flipped classroom, the majority of time was also devoted to allowing students to assimilate their knowledge through structured group problem-solving activities, small group discussions, and whole-class discussions, all under my guidance. Regardless of learning environments, in the flipped classroom, learning calculus was achieved by studying provided materials,
watching videos or other online resources, and completing brief assessments before attending class or at the start of class. In this study, online course design, online activities, and interactions impacted students’ sense of community. The breakout rooms' group work contributed to the building of connectedness and shared learning.

Students supported the argument that online learning communities provided the online space that is needed for rich discussions and meaningful connections among peers, content, and instructor to take place. In an online collaborative learning context, once students learned to solve new levels of problems and enhance their performance to the extent of their ZPDs by interacting with other competent students in the class, they gradually operated a self-regulatory process that transferred those new skills and knowledge into their individual minds. Students stated that they not only made connections between themselves and the content in those instances; they also gained insights from each other’s experiences and mistakes. Regardless, the learning environment, online activities, and tools, transformed the students into active learners who performed the tasks, engaged with the content and their fellow classmates.

**Students’ Perceptions and Challenges**

Constructivism encourages students to create their understanding and knowledge of the world through experiencing things and reflecting on those experiences (Gordon, 2009). Learning through Zoom triggered the student’s innate curiosity about technology and how things work. The constructivist perspective allowed the student to interact actively in the virtual classroom by constructing and transforming old concepts rather than being passive learners (Golding, 2011; Hyslop-Margison & Strobel, 2008). “Students do not reinvent the wheel but, rather, attempt to understand how it turns and how it functions” (Bada, 2015,p.67). They tried to derive their own personal intellect and construct their own interpretation (Driscoll, 2005). Within the virtual
classroom, students could participate in active learning with me and peers through activities such as class discussions, presentations, group collaboration, or reflective writing (Beer et al., 2010; Lundberg & Seridan, 2015; Price & Baker, 2012). In Lundberg and Sheridan’s (2015) study they confirmed that interaction among students and direct communication with faculty contributed to students’ involvement in the class and enhanced the overall learning experience. In particular, the constructivist activities that I developed for this study involved students in a community of learners—even in the virtual flipped classroom. I designed the activities to give students a positive experience that could bring meaning and value to the learning situation.

Like a face-to-face classroom, active online learning implies that learning in virtual environment can be a dynamic process whereby students are participating in constructivist learning. Synchronous teaching via Zoom technology and university online teaching platform, CANVAS, allowed me to maintain flipped learning and implement active learning during COVID-19 and switching to remote teaching. Researchers have found that synchronous communication also has a positive influence on group collaboration, understanding students’ learning attitudes, and student satisfaction (Lundberg & Seridan, 2015). One student said, “oftentimes, if a lesson is just a lecture or PowerPoint, it’s very easy to get distracted. Some students might retain, and some might not, but when we do lesson the way we are, I know that I actually understand how to put what we are learning into practice.”

Just like a face-to-face classroom, I was able to switch back and forth between different types of teaching methods such as lecture, small group discussion, concept map, error analysis, minute papers, and problem-solving. Chat rooms allowed students to communicate with others by typing into a text box that is sent directly to the other recipient. Lundberg and Seridan (2015)
established that chat rooms offered helpful support for students as they worked with one another to solve problems and understand the course material.

The interviewees compared their experiences of face-to-face versus Zoom flipped classes. They acknowledged that there was a similarity between the two teaching modalities. Nikki said she believed that I genuinely did the best in a very sudden switch to remote teaching. Students spoke very candidly about my teaching in Zoom and keeping them engaged in the virtual classroom.

In general, Zoom has some features such as whiteboard or breakout rooms by which I was able to keep students engaged. Students felt that it wasn’t so different than being in the Zoom classroom and having a face-to-face classroom. They confirmed that they absorbed the material the same way as if they were in the face-to-face classroom. However, students mentioned some challenges, such as losing the connection with other students, the faculty member, and the campus. They preferred face-to-face classes. Like previous research (Gillett-Swan, 2017; Gray & DiLoreto, 2016), participants of this study also struggled with feelings of isolation, technological difficulties, and personal obstacles created from family and work obligations. For most students, at least one aspect affected their ability to engage at the highest level. Some students expressed a sense of isolation because they were not able to attend classes on campus and have direct communication with their instructors and classmates (Gray & DiLoreto, 2016).

Technology has also become a challenge for both students and myself, as we had to learn new skills to use technology efficiently (Gillett-Swan, 2017). I had to make myself familiar with new technologies and apply new types of pedagogy within a virtual environment (Gillett-Swan, 2017). Gillett-Swan (2017) explained that the incorporation of technology created additional
work pressure and commitment of time as instructors are seeking the best type of technology to meet the needs of their online classroom.

My students were excellent and committed to learning. They understood the impact of the pandemic on everything, including their education. But sometimes, although they were doing Ok in virtual classroom, I could feel their frustration. They didn’t choose to learn online, but they had to. As Nick said, “it is not still the full experience. It’s not the same when you get to go to class and work with others.” But as Fady said, “in a major situation like this, I think that the tools offered in remote learning are still pretty good too.”

**Instructor’s Perception and Challenges**

My move from primarily face-to-face classes to 100% online teaching happened over a hectic week in March 2020. My university announced Tuesday evening that the campus would close for in-person classes until further notice, and next Monday, I was teaching my first completely online class using Zoom. I didn’t have enough time to prepare for such a huge change as my mind was focused on so many different things, such as my health and my family’s health. This concern was not exclusively for me. Students had the same concern or even more. In addition to the worrisome global situation, they were dealing with the loss of school support networks, on-campus jobs, subsidized housing, work-study programs, and access to technology. Many of them were struggling financially, academically, and emotionally as a result of campus closures.

However, COVID-19 was a global issue, and nothing could be done except adaptation. I spent hours learning how to make my flipped digital skills classes more interactive by using my iPad, apple pencil, different apps, and Zoom’s simultaneous desktop sharing, which allowed me
to more easily assist students who were struggling. My attempt was to create a relaxing environment and maintain active learning strategies. This was huge.

The Zoom classroom was the closest equivalent to the physical classroom that we could use during the pandemic. However, it was not yet a perfect replacement. When I am teaching an in-person class, I can see students’ faces, notice non-verbal cues, and gauge their engagement level in real-time. Then, I can make adjustments in my lecture, collaboration, group work, or even practicing in the class. During teaching virtually, all of these have vanished. Indeed, I did not mainly find satisfying the impersonal nature of teaching online. The lack of face-to-face connection and visual cues, which are typically seen in a classroom, did not provide my satisfaction. I missed the face-to-face interactions and spontaneous discussions that organically happen at a school. However, as I write this section of my dissertation, COVID-19 is still a terrifying disease, and panic has been indeed all around the world. In this uncertain situation, I am grateful for the technology and tools that kept us connected and continuous to let us keep going and have hope for the future.

Collaboration Virtually

Contrary to regular beliefs, online classes are capable of providing interactive learning experiences (Chen, 2007). Using proper technological tools and techniques can help create interactions in virtual classes (Smith, 2008). In considering the technological tools used in collaboration, students highlighted the variety of resources such as social media, Facetime, Skype, or email and text.

During the interviews, students indicated a mixed attitude and perception about the collaboration after we switched to the Zoom classroom. While some students believed they were able to collaborate and work in their group through Zoom, some others had concerns and issues.
Fady thought remote teaching didn’t impact collaboration in the flipped class classroom, and Mary stated: “We collaborated virtually more because we would watch the videos and then work on the homework together over Zoom or Snapchat.” Even though students were happy and satisfied with their collaboration in the virtual classroom, I had a feeling that mathematical discourse among them noticeably decreased. When I reviewed my journal, I see that my notes indicated this concern. I wrote, “it doesn’t seem all students do their activities, and some are quiet and not interactive.”

While synchronous virtual classrooms provided me the ability to interact with students instantly and afford the students the chance to participate in group activities in the breakout rooms, I had the feeling that students could not have the same opportunity of discussion as they had in face-to-face. I had many students who worked extremely well in groups and together, but I noticed that some students were resistant and did not collaborate well when they were in breakout rooms. They said they prefer to sit quietly and complete the work on their own. In general, online group work can create some challenges, such as questions of authority and interdependency (Smith, 2008a). Unlike the face-to-face classroom, in Zoom classroom, students did not have direct, physical access to my guidance, and I could not depend on them as knowledge authorities or facilitators in the group process( Shea & Bidjerano,2009)

Although I facilitated online discussion, students acknowledged each other as sources of authority and developed interdependency among each other to achieve goals(Shea & Bidjerano, 2009). I struggled to understand whether the group work is truly productive in breakout rooms since the learning was controlled by the group, not me. I was unable to decide if learning is taking place. Nevertheless, I understood that this process was new to students; therefore, some could feel unsettled or uncomfortable (Shea & Bidjerano,2009). Zack indicated that group
working was not working in a virtual classroom. He said, “I’m just speaking for me, but I think the weakest part of it [virtual classroom] was obviously by just doing group work.”

Sometimes, tensions among groups arose if someone developed a feeling of inequity or had a fear of the loss of her or his own voice and identity (Smith, 2008a); additionally, students became frustrated when some in their group did not contribute as much as others (Shea & Bidjerano, 2009). Due to the physical distance among students and the fact that they have to communicate via online technologies, all these processes—whether there is an explicit conflict or not, can be very challenging, especially since online students are likely to have insufficient opportunities to get to know each other well (Dirkx & Smith, 2004).

**Summary**

When I look back to the Spring semester of 2020, I remember that my most focus was on how I could use technology to teach and keep my research going. Even though Zoom gave me the opportunity to keep active and flipped learning in a virtual classroom, it was not able to connect me with my students emotionally. When I am teaching an in-person class, I can see students’ faces, notice non-verbal cues, and gauge their engagement level in real-time. Then, I can make adjustments in my lecture, collaboration, group work, or even practicing in the class. During teaching virtually, all of these have vanished. The lack of face-to-face connection and visual cues, which are typically seen in a classroom, did not provide my satisfaction.

By keeping students engaged, I was able to promote a sense of community. The data showed that students thought active learning does end up promoting their learning. However, it was not yet a perfect replacement. I tried to encourage students to communicate and collaborate, but it was a unique and unusual situation; we all worried about the health of ourselves and our loved ones. Some students panicked; they lost their job, or their parents had been laid off. It was
not easy to keep the same class environment that we had before the pandemic. While some students worked extremely well in groups, and together, some students were resistant and did not collaborate well. They have their own reasons such as internet issues, the right equipment, Zoom attacker, and so on. I had struggled with approving or disapproving of their excuses as well as motivating the unmotivated student. (April 29, 2020)

I missed the face-to-face interactions and spontaneous discussions that organically happens at a school. However, as I am writing this section of my dissertation, growing numbers of colleges and universities all across the world—including my university—are still dealing with the impact of the COVID-19 situation, and I am grateful for the sources that keep us still connected and lets us keep going and have hope for the future.

Implications for Practice

As an instructor, I seek consistent improvement in my practice to maximize learning and conceptual understanding in a trusting and collaborative environment. Based on this action research study’s results, the first implication for practice is that the flipped classroom has been judged as a viable method to educate. Students stated that flipped learning could improve their ability to ask questions, express viewpoints, and make practical applications. However, in the beginning, students were resistant to in-class activities, especially regarding group learning. Faculty should provide clear instructions to ensure better communication and efficiency in group activities so that every student in a flipped classroom knows their own learning objective and what to be discussed with their group members.

Second, the results also suggest that a flipped classroom consists of much more than videos and group work. Faculty thinking of implementing a flipped classroom must know that at the core of the flipped classroom is the necessity of completing pre-class activities. To be
successful, the pre-class activity must be interactive and connected with in-class activities. I recommend that instructors provide students in any flipped classroom with opportunities to activate their prior knowledge before entering into in-class activities. This helps instructors assist each student at his or her zone of proximal development and allows students to generate solutions freely, learn from their mistakes, and pursue assistance from peers and the instructor as needed.

A third important implication for practice is regardless of what type of in-class activity is used, one needs to consider the fact that time limits can be a challenge, and it is helpful for instructors to think through these challenges in advance. Creating resources, including problem sets, activities, and videos required in a flipped classroom, are time and labor-intensive. For me, it took a while to plan and create everything in a timely fashion, particularly after switching to online teaching. Nevertheless, if the lessons are scheduled with proper planning and organization, then the task at hand becomes much more manageable. One solution to overcome this problem is to use already created materials or to develop in-class learning activities in advance. Hence, the instructor has them available to utilize when necessary and appropriate.

Fourth, classroom management and organization during class is an integral part of implementing the flipped classroom approach. It is critical to organize a learner-centered classroom that supports active learning. Instructors should have careful consideration of the activities, establishing groups for collaboration, and time. Setting goals and a well-organized structure are necessary to reduce the chaotic atmosphere due to shifting from a teacher-centered learning environment to a learner-centered learning environment and from individual to collaborative strategies. This is a challenge and consideration in applying the flipped model of instruction in the future.
Finally, investigating some of the flipped classroom’s perceived barriers found in this study could be worthwhile in assisting in understanding some of these challenges better. I, personally, like to teach face-to-face. But in a significant situation like COVID-19, I had to switch to remote teaching. I recommend faculty be open and ready to teach in an alternative model in case of any future outbreak. At the beginning of teaching remotely, I thought this had to be an asynchronous online course, and I was not prepared for that. But it was not; I just was moving to synchronous remote instruction. This means to use traditional in-person instruction with some modifications.

During this uncertain time, I learned with my students. I understood that I could keep learning happening in my classes when I speak openly with students about being the right partners in learning. Students enjoyed the sense of taking control of their learning so that they don’t have to feel less powerless in a situation that is beyond their control. However, with all being said, the lack of face-to-face connection and visual cues, which are typically seen in a classroom, did not provide my satisfaction. In any teaching case, I recommend that faculty think about some activities in online courses such as discussion boards, reflection journals, and group work, which might increase interaction. To do so, faculty need training. So, academic administrators should strongly consider providing training courses on technological delivery and curriculum design for faculty to develop their online courses’ strategies further.

**Limitations and Strengths Suggestions for Future Research**

This section will discuss the limitations presented in chapter one and provide suggestions for future research.
Limitations and Strengths

Although the study’s findings support the efforts to broaden existing research related to the flipped classroom, several limitations of this study should be taken into consideration when reviewing the findings, implications, and recommendations. Firstly, one limitation of the study could be the fact that the experimenter is also the instructor. In other words, there was a potential that students simply respond that they thought I want to hear. To mitigate these issues, measures were taken in this study to ensure the participants’ anonymity, such as avoiding the collection of demographic information that could be used to triangulate certain participants’ identities. In addition, the students’ right to decline to participate without fear of repercussions was explicitly communicated.

Another limitation of this study is that my research didn’t consider the impact of factors such as algebra skills that might impede or supplement instruction, online sources, and college success courses that promote learning calculus.

Furthermore, even though in qualitative studies, the number of participants is usually less, the study’s small sample size can be another limitation. Bigger sample size would be needed to fully understand active learning in the general population to expand the results. To that point, a broader scope of students from different types of classes, ages, and levels would be required to grasp the efficacy of active learning in a classroom setting.

Finally, before starting the experiment, the base level of intelligence for each student should be accessed as blindly observing every student at the same level can be another limitation. Similarly, other aspects of the student, such as his/her work ethic, social habits, classroom behavior, etc., all need to be monitored as they can influence the study.
**Recommendations for Further Research**

Limitations of a study may open avenues for future studies. For example, prospective projects can observe a flipped classroom’s efficacy in other math courses and even in different subjects. This study was limited to one section in a single subject; therefore, a broader population yields substantially more results on active learning. Integrating students with varying ages, demographics, or levels permits more critical information that will reveal more about flipped learning. In addition, although the intention of this research was not to investigate the impacts of flipped learning on students' academic achievements, students in flipped calculus classroom scored higher compared to last semester (Fall 2019) who were taught in a traditional learning environment. This is a question that arose from this action research study that will need to be addressed in future iterations of the flipped classroom at our campus.

Moreover, future studies should observe if social behavior impacts the effectiveness of a flipped classroom. In reality, some students are more extroverted, which is demonstrated through their consistent classroom participation. However, other students are more reserved and engage less often. Hence, observing if a flipped classroom has divergent properties based on students’ social behavior and classroom habits can be an intriguing avenue for future experiments to delineate.

Lastly, future studies should include interviews and focus groups with participants in both traditional and flipped classrooms. Soliciting this qualitative feedback type from participants in both environments could lead to clear themes, perceptions, and benefits. Another aspect that would need to be considered is the experience within the flipped classroom style of those students who already prosper in lecture classes versus the students who are repeating the course. It would be beneficial to look into the retention rates of STEM majors with this
classroom structure to determine if this practice did make a difference in teaching students calculus.

**Final Reflections**

As an instructor myself, I have witnessed novice students’ anxious facial expressions beginning their journey into mathematics. However, in fairness, I must admit that I started the doctoral program with the same uneasiness and apprehension. English is not my native language, so as you can imagine, academic writing was a challenge. Furthermore, social science and qualitative research were miles away from my familiarity with numbers and mathematical figures. In addition to all of the above, as I got to the point of collecting my data and finishing my dissertation, other difficulties were encountered, this time out of my control. The novel Coronavirus forced a quick transition in my project, with new strategies to accommodate the situation.

In performing the study, observations on the different qualitative research practices were discerned, and its differences with quantitative research were evident. With quantitative research, the data is easier to gather as the experimenter collects information from the masses. Then, one sorts the numbers and explicates the significant results from them. In contrast, qualitative research is more hands-on and requires a greater interaction of the researcher with the participants. In truth, I was a bit concerned about this idea. Having students self-report and their comfortability with the process were aspects that were unique for me. However, I have realized that performing the interview process was one of the most enjoyable facets of the project. Being able to sit down and converse with each student about their experience instigated a fruitful discussion that could not be possible in quantitative studies. It brought a different perspective of directly hearing from students the pros and cons of their experience. Qualitative research
commences valuable data through the subject’s responses, which can initiate progressive action to better the learning process. Now, as I see the light at the end of a very long tunnel, my outlook on qualitative research and performing such studies has altered. Rather than viewing qualitative research with the apprehension and trepidation that I had at the beginning of the program, I have come to appreciate the research process and the diligence that comes with it.

While I am writing my dissertation’s final words, COVID-19 is still a global issue and has created the largest disruption of education systems in history. On the other hand, although a worldwide pandemic is not the ideal circumstance when completing a dissertation, I am a big believer in new challenges bestowing new opportunities. The COVID-19 changed how this study had to be carried out, with classes transitioning to online versions. I transitioned some of the techniques to be compatible with them. However, while the participants’ responses were positive and dynamic learning deemed compatible virtually through the use of the capabilities on various software such as Zoom, we all missed that social connectivity, which is key to promoting learning. We as humans are innately social creatures, and “it is through others that we develop to ourselves.” (Vygotsky, 1981, p. 161)
Date: January 9, 2020
From: Kimberly Petrosky,
To: Maryam Kiani

Type of Submission: Initial Study
Title of Study: An Exploration of Active Learning Calculus
Principal Investigator: Maryam Kiani
Study ID: STUDY00013910
Submission ID: STUDY00013910
Funding: Not Applicable

Documents Approved:
- APPENDIX VERSION 2.docx (0.02), Category: Data Collection Instrument
- HRP-591 - Protocol for Human Subject Research
  VERSION 2.pdf (0.02), Category: IRB Protocol

The Office for Research Protections determined that the proposed activity, as described in the above-referenced submission, does not require formal IRB review because the research met the criteria for exempt research according to the policies of this institution and the provisions of applicable federal regulations.

Continuing Progress Reports are not required for exempt research. Record of this research determined to be exempt will be maintained for five years from the date of this notification. If your research will continue beyond five years, please contact the Office for Research Protections closer to the determination end date.

Changes to exempt research only need to be submitted to the Office for Research Protections in limited circumstances described in the below-referenced Investigator Manual. If changes are being considered and there are questions about whether IRB review is needed, please contact the Office for Research Protections.

Penn State researchers are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within CATS IRB (http://irb.psu.edu).

This correspondence should be maintained with your records.

We would like to know how the IRB Program can better serve you.
Please fill out our survey; it should take about a minute: https://www.research.psu.edu/irb/feedback.
**APPENDIX B**

MATH140- Calculus with Analytic Geometry  
Spring 2020

Instructor: Prof. Kiani  
Meeting Days and Time:  
Section 01-Tu/Th 10:35AM - 11:50PM  
Room 224

E-mail: mxk57@psu.edu

Course Description: Math 140 (4): Functions, limits, analytic geometry; derivatives, differentials, applications, and integrals. Students may take only one course for credit from 140, 140A, and 140B. Prerequisites: MATH 022, MATH 026; or MATH 040 or MATH 041, or satisfactory performance on mathematics placement examination.

Materials:  
Calculus: Single and Multivariable 5th edition  
Hughes-Hallett, Gleason and McCallum, Published by John Wiley & Sons. For homework we use WebAssign. I will provide class key at the first day of class.  
CALCULATORS: A graphics calculator is useful as a study and learning tool when used appropriately, but it is not essential. Calculus is a collection of ideas that are not mastered through calculator skills. Calculators will not be allowed during quizzes or exams (all arithmetic computations will be simple enough to do by hand).

MATH 140 LEARNING OBJECTIVES: Upon successful completion of Math 140, the student should be able to:  
1. Use linear, exponential, and sinusoidal functions, as well as transformations, compositions, inverses, and piecewise combinations thereof to model real world scenarios.  
2. Calculate or estimate limits of functions given by formulas, graphs, or tables.  
3. Determine whether a function given by a graph or formula is continuous at a given point or on a given interval or on its domain.  
4. Determine whether a function given by a graph or formula is differentiable at a given point or on a given interval.  
5. Distinguish between average and instantaneous rate of change and interpret the definition of the derivative graphically.  
6. Determine derivatives of some functions using the limit definition of the derivative.  
7. Calculate derivatives of polynomial, rational, and common transcendental functions, and combinations of these functions.  
8. Calculate derivatives of composite functions.  
9. Calculate derivatives of implicitly defined functions and inverse functions.  
10. Give examples to illustrate important theorems. (Intermediate Value Thm, Rolle’s Thm, Mean Value Thm, Extreme Value Thm, Squeeze Thm)  
11. Apply the ideas and techniques of derivatives to related rate problems.  
12. Apply the ideas and techniques of derivatives to finding local and absolute extrema.  
13. Apply the ideas and techniques of derivatives to graphing functions.  
14. Apply the ideas and techniques of derivatives to optimization problems.  
15. Find linear approximations of functions (differentials).  
16. Calculate the Riemann sum for a given function and partition.  
17. Describe a definite integral as the limit of a Riemann sum.  
18. Determine antiderivatives of some algebraic functions and transcendental functions.  
19. Calculate values of definite integrals using antiderivatives and areas.  
20. Use the Fundamental Theorem of Calculus to determine the derivative of an integral.  
21. Use the
Fundamental Theorem of Calculus to evaluate definite integrals. Use the Net Change Theorem to solve accumulation problems. Determine the units and give the practical interpretation of derivatives and definite integrals. Synthesize concepts from two or more separate sections of the text. This course satisfies the General Education learning objectives Key Literacies and Critical & Analytical Thinking.

Assignments and Evaluation:

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<tr>
<th>Item</th>
<th>Points</th>
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<td>Class participation</td>
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<tr>
<td>Homework</td>
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<td>30</td>
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<tr>
<td>Tests (2)</td>
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<td>Quizzes (4)</td>
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Grading

- The following grading scale will be used:
  - A 95 – 100%
  - A- 90 – 94.9%
  - B+ 87 – 89.9%
  - B 84 – 86.9%
  - B- 80 – 83.9%
  - C+ 75 – 79.9%
  - C 70 – 74.9%
  - D 60 – 69.9%
  - F 59.9% or below

Semester Calendar

<table>
<thead>
<tr>
<th>Days</th>
<th>Topics</th>
<th>Activities</th>
<th>Comments</th>
<th>Highlight</th>
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<tr>
<td>Week#1</td>
<td>Four ways to represent a function</td>
<td>Course Introduction</td>
<td>Watch video</td>
<td>Questioner #1 Due</td>
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<td>Research Introduction</td>
<td>Study next week</td>
<td>Get ready for next week class</td>
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<td>01/16</td>
<td>Different functions and their domain and</td>
<td>Consent Form</td>
<td>Pre-Class Learning Assignments (PCLA)</td>
<td>presentation</td>
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<td></td>
<td>range</td>
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<td>Do After-class learning Assignments</td>
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<td></td>
<td></td>
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<td>(ACLA)</td>
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<td>Week#2</td>
<td>Limit of a function</td>
<td>Lecture Group discussions,</td>
<td>Watch video</td>
<td>Tuesday:</td>
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<td>group work on problems,</td>
<td>Study next week</td>
<td>Group</td>
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<td>01/23</td>
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<td>Pre-Class Learning</td>
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<tr>
<td>Group discussions, group work on problems, peer review, and instructor’s feedback.</td>
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<td><strong>Watch video</strong></td>
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<td><strong>Do After-class learning Assignments (ACLA)</strong></td>
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<td><strong>Pre-Class Learning Assignments (PCLA)</strong></td>
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<td><strong>Quiz#1</strong></td>
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<td><strong>Questioner #2 Due</strong></td>
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<td><strong>Group Presentation# 2</strong></td>
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<td><strong>Homework#2 Due</strong></td>
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<tr>
<td><strong>Minutes paper on PCLA and ACLA</strong></td>
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<thead>
<tr>
<th>Week#4</th>
<th>02/04-02/06</th>
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<tbody>
<tr>
<td><strong>Derivatives and rates of change</strong></td>
<td></td>
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<tr>
<td><strong>Differentiation formulas</strong></td>
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<tr>
<td>Lecture</td>
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<td>Group discussions, group work on problems, peer review, and instructor’s feedback.</td>
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<td><strong>Watch video</strong></td>
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<td><strong>Do After-class learning Assignments (ACLA)</strong></td>
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<td><strong>Pre-Class Learning Assignments (PCLA)</strong></td>
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<td><strong>Do After-class learning Assignments (ACLA)</strong></td>
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<td><strong>Group Presentation# 3</strong></td>
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<td><strong>Homework#3 Due</strong></td>
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<td><strong>Minutes paper on PCLA and ACLA</strong></td>
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<td><strong>Watch video</strong></td>
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<td><strong>Do After-class learning Assignments (ACLA)</strong></td>
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<td><strong>Pre-Class Learning Assignments (PCLA)</strong></td>
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<td><strong>Do After-class learning Assignments (ACLA)</strong></td>
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<td><strong>Questioner #3 Due</strong></td>
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<tr>
<td><strong>Group Presentation# 4</strong></td>
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<tr>
<td><strong>Homework#4 Due Test#1</strong></td>
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<tr>
<td><strong>Minutes paper on PCLA and ACLA</strong></td>
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</table>
| Week#6 02/18 02/20 | Trigonometric derivatives  
Chain rule | Assignments (ACLA)  
Minutes paper on PCLA and ACLA | Tuesday:  
Watch video  
Study next week Pre-Class Learning Assignments (PCLA)  
Do After-class learning Assignments (ACLA)  
Thursday:  
Questioner #4 Due  
Group Presentation #5  
Homework #5 Due  
Minutes paper on PCLA and ACLA |
|-------------------|-----------------------------|----------------------------------|-------------------------------------|
| Week#7 02/25 02/27 | Implicit derivatives  
Related rates | Assignments (ACLA)  
Minutes paper on PCLA and ACLA | Tuesday:  
Watch video  
Study next week Pre-Class Learning Assignments (PCLA)  
Do After-class learning Assignments (ACLA)  
Thursday:  
Questioner #4 Due  
Group Presentation #6  
Homework #6 Due  
Quiz #2  
Minutes paper on PCLA and ACLA |
| Week#8 03/3 03/5 | Derivatives and graphs  
Maximum and minimum values | Assignments (ACLA)  
Minutes paper on PCLA and ACLA | Tuesday:  
Watch video  
Study next week Pre-Class Learning Assignments (PCLA)  
Do After-class learning Assignments (ACLA)  
Thursday:  
Questioner #4 Due  
Group Presentation #7  
Homework #7 Due  
Minutes paper on PCLA and ACLA |
| Week#9 03/10 03/12 | SPRING BREAK | Assignments (ACLA)  
Minutes paper on PCLA and ACLA | Tuesday:  
Watch video  
Study next week Pre-Class Learning Assignments (PCLA)  
Do After-class learning Assignments (ACLA)  
Thursday:  
Questioner #4 Due  
Group Presentation #8  
Homework #8 Due  
Quiz #3  
Minutes paper on PCLA and ACLA |
<table>
<thead>
<tr>
<th>Week#10</th>
<th>Maximum and minimum values Limits at Infinity; Horizontal Asymptotes</th>
<th>Lecture Group discussions, group work on problems, peer review, and instructor’s feedback.</th>
<th>Watch video Study next week Pre-Class Learning Assignments (PCLA) Do After- class learning Assignments (ACLA)</th>
<th>Tuesday: Questioner #5 Due Group Presentation# 8 Homework#8 Due Test#2 Thursday: Minutes paper on PCLA and ACLA</th>
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<td>Week#11</td>
<td>Curve Sketching Optimization</td>
<td>Lecture Group discussions, group work on problems, peer review, and instructor’s feedback.</td>
<td>Watch video Study next week Pre-Class Learning Assignments (PCLA) Do After- class learning Assignments (ACLA)</td>
<td>Tuesday: Group Presentation# 9 Homework#9 Due Thursday: Minutes paper on PCLA and ACLA</td>
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<td>03/26</td>
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<tr>
<td>Week#12</td>
<td>Antiderivative Substitution rules</td>
<td>Lecture Group discussions, group work on problems, peer review, and instructor’s feedback.</td>
<td>Watch video Study next week Pre-Class Learning Assignments (PCLA) Do After- class learning Assignments (ACLA)</td>
<td>Tuesday: Questioner #6 Due Group Presentation# 10 Homework#10 Due Quiz#3 Thursday: Minutes paper on PCLA and ACLA</td>
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<td>03/31</td>
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<td>04/2</td>
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<tr>
<td>Week#13</td>
<td>Definite Integral Fundamental Theorem of Calculus</td>
<td>Lecture Group discussions, group work on problems, peer review, and instructor’s feedback.</td>
<td>Watch video Study next week Pre-Class Learning Assignments (PCLA)</td>
<td>Tuesday: Group Presentation# 11 Homework#11 Due</td>
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<tr>
<td>04/7</td>
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<td>04/9</td>
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<tr>
<td>Week#14 04/14 04/16</td>
<td>Area</td>
<td>Lecture Group discussions, group work on problems, peer review, and instructor’s feedback.</td>
<td>Watch video Study next week Pre-Class Learning Assignments (PCLA) Do After- class learning Assignments (ACLA)</td>
<td>Tuesday: Questioner #7 Due Group Presentation# 12 Homework#12 Due Quiz#4 Thursday: Minutes paper on PCLA and ACLA</td>
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<tr>
<td>Week#15 04/21 04/23</td>
<td>Volumes by Disk/washer</td>
<td>Lecture Group discussions, group work on problems, peer review, and instructor’s feedback.</td>
<td>Watch video Study next week Pre-Class Learning Assignments (PCLA) Do After- class learning Assignments (ACLA)</td>
<td>Tuesday: Group Presentation# 13 Homework#13 Due Thursday: Minutes paper on PCLA and ACLA</td>
</tr>
<tr>
<td>Week#16 04/28 04/30</td>
<td></td>
<td></td>
<td>Watch video Study next week Pre-Class Learning Assignments (PCLA) Do After- class learning Assignments (ACLA)</td>
<td>Tuesday: Questioner #8 Due Group Presentation# 14 Homework#14 Due Thursday: Minutes paper on PCLA and ACLA</td>
</tr>
<tr>
<td>05/1-05/5</td>
<td>Final Exam Week</td>
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</tbody>
</table>
APPENDIX C
PARTICIPANT CONSENT FORM
Informed Consent Form
The Pennsylvania State University
Title of Project: An Exploration of Active Learning Calculus: An Action Research
Principal Investigator: Maryam Kiani
Penn State Lehigh Valley
Mxk57@psu.edu
610-285-5233
Advisor: Dr. Robin Redmon Wright W314 Olmsted Building 777 W. Harrisburg Pike
Middletown, PA 17057 (717) 948-6405;
rrw12@psu.edu

You are being invited to volunteer to participate in a research study. This summary explains information about this research.

**Purpose of the Study:** The purpose of this study is to explore how learners and instructor experience learning calculus when active learning and learner-centered methods are implemented.

**Procedures to be followed:** This study is designed using an action research methodology, which means that it will be constantly evolving and be shaped to meet the needs of the participants. Feedback from the participants will enable the Principal Investigator to work towards improving success in learning calculus. The participants will be asked to provide data that will be collected over the 15 week semester from surveys, minute papers, faculty evaluations, and interviews. The surveys will take place at the beginning, biweekly, and mid-point of the semester. Interviews will be completed within the last two weeks of the semester and will take no longer than 60 minutes. They will be audiotaped and transcribed. The surveys, minute papers, interviews, and faculty evaluations will not be graded.

**Discomforts and risks:** There are no risks in participating in this research beyond those experienced in everyday life. Participation or non-participation will not have any effect on your grade for the class or any known effects.
**Duration/time of the procedures and study:** This study will be conducted within a single academic semester.

**Statement of confidentiality:** All of the information collected during this study, including any information that directly links you to the study or identifies you, will be kept confidential. No personal numeric data (i.e. social security numbers, birthdates, telephone numbers, etc.) will be used to identify participants. In the event of a publication or presentation resulting from the research, no personally identifiable information will be shared. The collected data will be stored and secured at the Principal Investigator’s office in a locked file cabinet and password protected files on her computer.

Option for the use of coursework: May the Principal Investigator use your coursework, responses to surveys, or other information for research purposes? Please choose one response:

_____ I DO give my consent to have my work included in the study.

_____ I DO NOT give my consent to have my work included in this study.

Option for tape recording: May the Principal Investigator audio tape the interviews conducted within the last two weeks of the semester?

Please choose one response:

_____ I DO give my permission to be audio/digitally taped.

_____ I DO NOT give my permission to be audio/digitally taped.

Your participation is voluntary and you may decide to stop at any time. You do not have to answer any questions that you do not want to answer. You must be 18 years of age or older to consent to take part in this research study. If you agree to take part in this research study and the information outlined above, please sign your name and indicate the date below.

You will be given a copy of this consent form for your records.

Participant Name (Please print) Date ________________________________

Participant Signature Date ________________________________

Person Obtaining Consent Date ________________________________
APPENDIX D

Example of Pre-Class Assignment

Guided Practice for 1.1: Four ways to represent a function/the concept of limit

Overview

Our study of calculus begins with a basic building block for understanding function and different form of functions. Four forms of functions are introduced in the section and connected to the concept of the limit.

Learning objectives

BASIC learning objectives

Each student will be responsible for learning and demonstrating proficiency in the following objectives PRIOR to the class meeting. The entrance quiz (minute paper) for the class meeting will cover these objectives.

Linear, exponential, and power functions
Transformations, compositions,
Inverses
Piecewise
Real world application
Explain the differences between the Exponential functions and power function

ADVANCED learning objectives

Each student should master the following objectives DURING and FOLLOWING the class session through active work and practice:

- Write an example of each function
- Calculate this function at x=3
- Add /subtract/multiply /and divide the function
- Limit Laws

Resources

Reading: Notes, book
**Viewing:** Watch the following videos (the videos will be provided)

**Exercises (will be created)**

These exercises can be done during or after your reading and watching the video. They are intended to help you make examples of the concepts you are reading and viewing. Work these out on scratch paper, and then you will be asked to submit the results on a web form at the end.
APPENDIX E

LIST OF VIDEOS

This appendix displays some examples of videos:

*Differentiation Unit Videos, Descriptions, and Alignment*

<table>
<thead>
<tr>
<th>Title</th>
<th>Descriptions</th>
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<tbody>
<tr>
<td><strong>Basic Derivative Rules:</strong> Basic derivative rules including derivatives of a constant, sum and difference, and power rule; basic trigonometric derivatives</td>
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</tr>
<tr>
<td><strong>Product, Quotient Rules, and Chain Rule:</strong> Product and quotient rules including reciprocal and quotient trigonometric function derivatives</td>
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<tr>
<td><strong>Graphs of Derivatives &amp; Tangent Lines:</strong> Limit definition of a derivative and its relation to slope; determining the graph of a derivative based on knowledge of slopes; finding the equation of a tangent line</td>
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<tr>
<td><strong>Rates of Change and Particle Motion:</strong> Notation for real world problems; Average versus instantaneous rates of change; relationship between position, velocity, and acceleration; relationship between velocity and speed; determining whether an object is speeding up or slowing down</td>
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<tr>
<td><strong>Evaluating Derivatives &amp; Tangent Approximations:</strong> Evaluating derivatives from graphical representations or data in tables; using a tangent line to approximate a value of a function</td>
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<tr>
<td><strong>Implicit Differentiation:</strong> The method for implicit differentiation; notation for taking the derivative with respect to any variable</td>
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<tr>
<td><strong>Related Rates:</strong> Applying implicit differentiation to real world problems; a triangle problem relating the rate of a moving ladder to the changing of the sides of the triangle</td>
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<tr>
<td><strong>Integral:</strong> Calculate values of definite integrals using antiderivatives and areas. Use the Fundamental Theorem of Calculus to determine the derivative of an integral. Use the Fundamental Theorem of Calculus to evaluate definite integrals.</td>
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<tr>
<td><strong>Volume:</strong> Find the volumes by using definite integrals</td>
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</table>
## APPENDIX F
### In-class Learning Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Model (Individual, pair, Group)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jigsaw</td>
<td>Group</td>
<td>Students are assigned a different objective or “type” of problem. They relearn that objective and then change groups and ensuring that each group contains members with different objectives. Each student then re-teaches their objective to the new group.</td>
</tr>
<tr>
<td>Concept Mapping</td>
<td>Individual, pair, or Group</td>
<td>Students make a summary of the topics and create a map that connects conceptual meaning.</td>
</tr>
<tr>
<td>Error Analysis</td>
<td>Individual, Pairs</td>
<td>Students should find the error in process or solution and correct it. Instructor can explore students’ thought processes and use that work to diagnose misconceptions.</td>
</tr>
<tr>
<td>Exit Ticket</td>
<td>Individual</td>
<td>To assess what students learned from a class session, they complete a short write on what they didn’t understand.</td>
</tr>
<tr>
<td>Think-pair-share</td>
<td>Pairs</td>
<td>Students think about a question, discuss their thinking with a partner, and then verbally share their ideas in class.</td>
</tr>
<tr>
<td>One-Minute Paper</td>
<td>Individual</td>
<td>Students address their struggle about new topic.</td>
</tr>
<tr>
<td>Roundtable Exercise</td>
<td>Group</td>
<td>The first student in the group completes the first step of work then passes the problem to the next person. The second person completes the second step of work and passes the work to the third person. This process continues until the work is finished.</td>
</tr>
<tr>
<td>Function creation</td>
<td>Individual</td>
<td>Students create a function with their favorite number and variable. Then make derivative and integral of the same function.</td>
</tr>
<tr>
<td>Inquiry-Based Learning</td>
<td>Group</td>
<td>Students work on tasks that require them to solve problems, conjecture, experiment, explore, create, and communicate, all critical skills and habits of mind.</td>
</tr>
</tbody>
</table>
APPENDIX G

REFLECTIVE JOURNAL

Reflective Journal Observation Chart

Date:

Observations :

Time :

Class Activity :

Reflection/Comment

1. What are my thoughts and feelings about today’s class? Justify my answer.

2. What worked? Justify my answer.


4. What did I learn from the experience today?

5. Are there any changes I would make to improve today’s experience/class?
APPENDIX H
First Week Survey

1. My placement in calculus was determined by (Mark all that apply)
   - My SAT or ACT score
   - My placement test (ALEX)
   - My successful completion of prerequisite course
   - MY AP exam score
   - Don’t know

2. Did you take the SAT exam?
   - What was your score?

3. Did you take the ACT exam?
   - What was your score?

4. What was your last math course that you took?
   - Algebra I
   - Algebra II
   - Statistics
   - Trigonometry

5. Do you think learning Calculus is important.
   - Yes
   - No

6. Do you think Calculus is useful for other Science, Technology, Engineering, Math (STEM) fields of study?
   - Yes
   - No

5. Did you take pre-calculus or calculus prior this course?
   If yes, how you describe your math teacher:
   - Lectured all the time
   - Primarily showed us how to get answer to specific question
   - Frequently had us work in-group
Gave us challenging questions

Please answer briefly the next two questions.

6- What comes to your mind when you hear mathematics?

7- Please describe one of your bad or good memory about learning mathematics?
APPENDIX I

Biweekly Critical Incident Questionnaire (CIQ)

1. The times in class that I have been most engaged:
   a) Lecturing                  b) Math Activity in Group        c) Math Activity Individually
   d) Taking Notes              e) Do a problem on the board    f) None

2. The times I have been least engaged
   a) Lecturing                  b) Math Activity in Group        c) Math Activity Individually
   d) Taking Notes              e) Do a problem on the board    f) None

3. The most important thing I’ve learned about active learning in the past two weeks (apply all that are applicable)
   a) Helped me to be engaged    b) Helped me to learn better    c) Helped me to be focused
   d) Helped me to interact with others. e) None

4. One comment I’d make about my experience of the inverted classroom in the past two weeks is
APENDIX J
Mid-semester Survey
Place an “X” or checkmark in the appropriate circle. You can make a comment for each question.

1) The flipped classroom makes it easier to understand the course content.
   - Yes
   - No
   Comment:

2) The flipped classroom gives me greater opportunities to communicate with other students.
   - Yes
   - No
   Comment:

3) The flipped classroom is more engaging than traditional classroom instruction.
   - Yes
   - No
   Comment:

4) I am more motivated to learn mathematics in the flipped classroom.
   - Yes
   - No
   Comment:
5) I would not recommend the flipped classroom to a friend.
   
   o  Yes  
   o  No  
   
   Comment:

6) What are the advantages of the flipped classroom?

7) What are the disadvantages of the flipped classroom?

8) What improvements would you recommend to improve learning in the flipped classroom?

9) Please add any other comments you wish to make about the flipped classroom.
APPENDIX K

End of Semester Interview

1.) What do you think about learning calculus?
2.) What has been your experience of learning calculus in this course? Can you compare learning calculus in flipped classroom with traditional classroom?
3.) How would you describe your experiences regarding inverted learning?
4.) What was the environment/atmosphere like in the inverted classroom?
5.) What have you found helpful in the course this semester? What have you found to be a challenge?
6.) What part(s) of the inverted classroom do you find most helpful? Least helpful?
7.) Describe your experience working in small groups and learning in collaboration with your fellow students.
8.) What did you find challenging about working in the small groups?
9.) What do you think about my role during the in-class activities?
10.) Overall, what is your impression of the inverted classroom?
11.) Do you recommend inverted classroom to any of your friend?
12.) How did the inverted classroom impact your calculus learning this semester? Did it help or hinder? Why or why not?
13.) Describe how the inverted classroom has changed or not changed your perception of learning calculus.
14.) How would you describe your experiences regarding virtual classroom learning?
15.) Do you think active learning was maintained in virtual classroom?
16.) Was I able to keep you engaged in virtual classroom?
17.) Do you prefer an online course or face-to-face? Why?
18.) How do you describe group learning in virtual classroom?
19.) What were the challenges that you faced in this class during pandemic?
20.) How do you describe the effect of virtual learning on your achievement and attitude?
# APENDIX L
## Weekly Schedules

### Week 3-4

#### Week #3

<table>
<thead>
<tr>
<th>Objective(s)</th>
<th>Limits</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Pre-Class Assignments</td>
<td>Watch video#3 and take the notes.</td>
<td></td>
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<tr>
<td></td>
<td>Do pre-class assignment #3</td>
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<tr>
<td>In-Class Activities</td>
<td>Entrance Quiz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Jigsaw activity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Minute paper/ Think-pair-share</td>
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<tr>
<td>After-class Activities</td>
<td>Homework#3</td>
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</tbody>
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#### Week #4

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<tr>
<th>Objective(s)</th>
<th>Limits</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Class Assignments</td>
<td>Watch video#4 and take the notes.</td>
<td>Quiz #2</td>
</tr>
<tr>
<td></td>
<td>Do pre-class assignment #4</td>
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<tr>
<td>In-Class Activities</td>
<td>Entrance quiz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Roundtable Exercise</td>
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<td></td>
<td>Complete Critical incident questionnaires#2</td>
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<tr>
<td>After-class Activities</td>
<td>Homework#4</td>
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#### Week 5-6

#### Week #5

<table>
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<tr>
<th>Objective(s)</th>
<th>Differentiation Formula</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>Pre-Class Assignments</td>
<td>Watch video#5 and take the notes.</td>
<td>Test#1</td>
</tr>
<tr>
<td></td>
<td>Do pre-class-assignment #5</td>
<td></td>
</tr>
<tr>
<td>In-Class Activities</td>
<td>Entrance Quiz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Error Analysis</td>
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<tr>
<td></td>
<td>One-Minute Paper</td>
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</table>
### Week #6

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<th>Objective(s)</th>
<th>Differentiation Formula</th>
<th>Notes</th>
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<tbody>
<tr>
<td>Pre-Class Assignments</td>
<td>Watch video#6 and take the notes. Do pre-class assignment #6</td>
<td>Quiz#3</td>
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<td>In-Class Activities</td>
<td>Entrance Quiz Jigsaw Minute Paper: “What You Didn’t Understand?” Test Correction Complete Critical incident questionnaires#3</td>
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| After-class Activities | Homework#5                                      |           |

### Week 7-8

#### Week 7

<table>
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<td>Pre-Class Assignments</td>
<td>Watch video#7 and take the notes. Do pre-class assignment #7</td>
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<td>In-Class Activities</td>
<td>Entrance Quiz Error analysis. Complete study guide for week Minute Paper: “What You Didn’t Understand?”. Inquiry-Based Learning One-Minute Paper</td>
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| After-class Activities | Homework#7                                      |           |

### Week #8
### Week 9-10

#### Week #9

<table>
<thead>
<tr>
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<td>Pre-Class Assignments</td>
<td>Watch video#8 and take the notes. Do pre-class assignment #8</td>
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<td>Entrance Quiz</td>
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<td>Jigsaw</td>
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<td>Complete Critical incident questionnaires#4</td>
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#### Week #10

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<td>Pre-Class Assignments</td>
<td>Watch video#9 and take the notes. Do pre-class assignment #9</td>
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<table>
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<tr>
<td>Entrance quiz</td>
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<td>Inform students about Zoom classroom</td>
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<td>Concept map</td>
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<td>Exit Ticket</td>
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<td>Pre-Class Assignments</td>
<td>Watch video#10 and take the notes. Watch Zoom recording Do pre-class assignment #10</td>
<td>Quiz#5</td>
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<table>
<thead>
<tr>
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<tr>
<td>Entrance Quiz</td>
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<tr>
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### Week 11-12

#### Week# 11

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<td>Pre-Class Assignments</td>
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<td></td>
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#### Week# 12

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<td>Watch video#12 and take the notes.</td>
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<td>In-Class Activities</td>
<td>Entrance Quiz</td>
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<td>Complete Critical incident questionnaires</td>
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### Week 13-14

#### Week# 13
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<td>Pre-Class Assignments</td>
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Week# 14

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<td>Complete end of semester survey</td>
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APENDIX M
Faculty Evaluation

Reporting Date: 12/6/2020 9:58 AM
Instructor ID: mxk57
Term: 2201

Semester: 2019/20 SP
Instructor: Maryam Kiani
Session: 1
Campus: LV
College: SC

<table>
<thead>
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<th>Course ID</th>
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<td>H2</td>
<td>32</td>
<td>7</td>
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Unrestricted Items

M 1  What did you like most about this course?

I most liked Professor Kiani’s desire for everyone to learn.

The Professor was the favorite thing about this course. She made me become more engaged with calculus.

I liked how homework and tests were used effectively and not assigned just for busywork.

Her attitude for math

Kiani in general, her attitude, preparation, everything she does was amazing.

I liked that she had more of a focus on getting students to learn a concept, rather than caring about a slight miscalculation. For instance, as long as you understood each individual step and could show work for it, there would be partial credit given even if the final numerical was off.

Professor Kiani as a teacher, the course made me think

University Open Ended Items

Open 1  What helped you learn in this course?

Professor Kiani is amazing at presenting a clear and quick-cut way of learning. She sticks to the main idea and doesn't add any fluff. She always gave hard examples which helped me solve all sorts of questions.

The abstract ways in which the instructor described topics to really stimulate thinking and understanding.

I really loved the professor’s charisma and excitement with helping us learn calculus! She was phenomenal and made me excited learning math.

Professor Kiani randomly calling on me helped a lot. It would make sure I kept my focus.

Determination

The Professor mostly helps with my learning inside and outside the classroom. Because of COVID, I felt that she was a bit ineffective outside of class (which isn't her fault) but it hindered my learning somewhat.

The short and weekly homework helped me remember the material.
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VITA
Maryam Kiani

Education

The Pennsylvania State University, Harrisburg, PA (May, 2021)
- Doctor of Lifelong Learning and Adult Education

Desales University, Center valley, PA (May, 2010)
- M.Ed. Mathematics Education

University of Tehran, Iran (December, 2003)
- M.S. Mathematics

Teaching Experiences

- Penn State -Lehigh Valley (2009 – present)
- Northampton Community College, PA (2010-2013)

Honors or Awards

- Teaching Excellence Award (2014)
- Outstanding Part time Teaching Excellent Award (2012)

Papers, Presentations, Seminars, and Workshops