5-2022

Increasing Active Learning and Achievement in a Large Lecture Calculus Class Through a Flipped Classroom Model

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in Curriculum and Instruction

by

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May 2022
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Abstract

University Calculus I courses serve as a means of access into high demand STEM fields and large lecture style passive calculus courses can be difficult for students. A mixed methods research design was used to compare a flipped instructional approach to a traditional lecture approach in large section Calculus I courses. The flipped lecture model required students to view videos of calculus instruction that included embedded quiz questions to allow for problem solving explorations during face-to-face class time. The traditional format included content from the video and limited time for additional problem solving. A professor with prior experience teaching Calculus I taught both sections. The results showed that students in the flipped class scored significantly higher on the final exam than the students in the traditional class. Student pass rates in the two Calculus I courses were found to be significantly affected by the lecture type, sex, race, and college affiliation. According to a logistic regression model, students who were in the flipped section had increased odds of passing Calculus I compared to the students in the traditional section. The students and instructor identified benefits and challenges of the flipped lecture model that are included in the results. Through the flipped lecture model, increased time was spent on active learning and student outcomes were improved in a large lecture calculus course.

Acknowledgements

This dissertation would not have been possible without the support and knowledge of the excellent faculty members at the University of Arkansas. I would like thank my committee including my advisor Dr. Laura Kent for all of her advice and helping me navigate the dissertation experience. Dr. Shannon Dingman graciously agreed to teach the two courses in this study and constantly provided guidance throughout the process. Dr. Wen-Juo Lo went above and beyond by providing advice with the statistical analysis. Dr. Kathleen Collins provided guidance on the mixed methods. Dr. Nama Namakshi was an encouraging voice throughout the process. I also want to thank Dr. Mark Johnson for allowing me to conduct this study in the Department of Mathematics at the University of Arkansas. Outside of the University of Arkansas, there were several people who helped to make my graduate school journey a success. I want to thank my husband Zachary King not only for his consistent calming advice, but also for his support and encouragement during the process of pursuing a PhD. I want to thank my friend and former colleague Jennifer Adams for being a sounding board throughout the dissertation process. My former colleagues at the University of Arkansas Fort Smith encouraged me to pursue a PhD. I needed that extra push of encouragement to get started. I would also like to thank my parents and in-laws who helped with taking care of my children when I was taking night classes, and my children for their patience with me and their encouragement while I worked on my dissertation. "You can do it mama!"

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Chapter 1 Introduction

The goal of this study was to learn about the experience of the students and instructor in a flipped undergraduate Calculus I course as well as examine the outcomes of the students in the flipped classroom compared to the outcomes of students in a traditional classroom model. The outcomes of the flipped and traditional Calculus I courses were examined by comparing grades and pass rates for students while considering the students' demographic information. The benefits and challenges of the flipped lecture model were examined by surveying the students and instructor in the flipped lecture course.

Research Questions

The questions that this study explored include:

1. What was the difference in final exam scores between students enrolled in a traditional large lecture calculus class and students enrolled in a flipped large section calculus class? (Quantitative)
2. How were final pass rates of subpopulations (minority status, college affiliation and gender) of students different for students enrolled in a traditional large lecture calculus course and students enrolled in a flipped large section calculus course? (Quantitative)
3. How did the attitudes of students toward mathematics in the flipped lecture course compare to students in the traditional lecture course? (Quantitative)
4. How did the flipped classroom model affect students' plans to pursue Calculus II? (Integrated)
5. What were the benefits and challenges of a flipped large lecture calculus course? (Integrated)

Literature, Context and Background

Teaching undergraduate calculus is as challenging as it is crucial to the success of any STEM program. Calculus I has repeatedly been linked to students' decisions to leave majors in the STEM fields (Chen 2013; Ehrenberg 2010; Steen, 1988). Bressoud et al. (2015) noted that, "Calculus occupies a unique position as gatekeeper to the disciplines in science, technology, engineering, and mathematics (STEM)." (p. v). This is one and a half times more likely for women in STEM fields, according to Ellis et al. (2016). If this gatekeeper can become a pipeline, then higher-education institutions will be able to grow their STEM programs and prepare their students for high-demand STEM fields. According to Bressoud et al. (2015), "Success rates in calculus for women, students from underrepresented minorities, economically disadvantaged students, and first-generation college students have always been disappointing. The loss of these students is a luxury our nation cannot afford. (p. v)"

According to Bressoud et al. (2015),

> our colleges and universities find themselves in the vise created by the dramatic growth in the number of incoming students hoping to pursue careers in engineering or science pressed against the drastic budget cuts that have forced departments to reduce the number of full-time faculty and to teach calculus in ever larger classes. (p. v).

Hornsby and Osman (2014) noted that large lecture courses are counterproductive to developing critical thinking skills, but because of financial constraints and large numbers of students interested in STEM fields they are here to stay. Bressoud and Rasmussen (2015a) conducted a survey of undergraduate calculus courses and noted that "Calculus I, as taught in our colleges and universities, is extremely efficient at lowering student confidence, enjoyment of mathematics, and desire to continue in a field that requires further mathematics. (p. 144)". However, Bressoud and Rasmussen (2015a) noted seven characteristics that lead to successful calculus programs. Two of those characteristics were "use of student-centered pedagogies and active learning strategies (p. 145)" and "effective training of graduate teaching assistants (p. 145). There are multiple studies that indicate that inquiry-based and active approaches to the teaching of mathematics have a positive impact on student learning, especially for women and minority students and increase retention in STEM (Freeman et al. 2014; Laursen, Hassi, Kogan, & Weston, 2014; Rasmussen & Kwon, 2007). Rasmussen and Ellis (2013) defined "Progressive" teaching as "instructional approaches that more actively engages students" (p. 462). They found that students who originally planned to go on to Calculus II are more likely to persist when instructors have used progressive instruction. Prensky (2001) referred to today's learners as "digital natives" and noted that this generation of students preferred to have access to information at their fingertips and to learn in active and collaborative environments.

Lage et al. (2000) was one of the first researchers to define what is now known as a flipped or inverted classroom: "Inverting the classroom means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa (p. 32)." Flipped classrooms have gained popularity as an instructional approach. According to Jungic et al. (2015), the favor of the flipped instructional model has increased due to the availability of video technology. In a large public university with large section calculus courses, engaging students in active learning can be a daunting task. According to Hong et al. (2017), "Changing instructional practices in calculus is very challenging." (p. 434). Though many mathematicians recognize the need for more cognitively demanding tasks, it is difficult to incorporate this into the current collegiate environment. Hong et al. (2017) mentioned that the professors in his study cited time constraints and underprepared students as the two main reasons that implementing student centered teaching is challenging. According to Bergman and Sams (2012), a flipped classroom gives instructors time to pursue inquiry and problem-based learning in class while moving the lecture and definitions to video. Larsen et al. (2015) interviewed an instructor after flipping a class and they observed that “the online videos freed up time in class to get students to think more deeply about problems, make connections, think in a more abstract way and solve more complex problems (p. 102).” Other benefits of flipped class instruction were increased student engagement and motivation, increased content knowledge, the opportunity for students to pause rewind and review segments of video, and increased peer to peer or peer to instructor interaction (Bergman & Sams, 2012). Additionally, Teo et al. (2014) noted reduced learning anxiety and improved efficiency in the flipped classroom.

The results of studies of flipped instructional approaches are mixed. Adams and Dove (2018) found increased achievement, but no difference in students’ beliefs about mathematics, while Scott et al. (2016) found no difference in knowledge gained by students, but found that the flipped class was more effective at increasing interest in mathematics. Overall, the evolving research is positive for flipped mathematics courses. Though various aspects of flipped undergraduate calculus courses have been studied, there is limited research of how the flipped classroom effects women and minority students especially in large lecture settings. Active learning has been tied to increases in calculus success for women and minority students (Bressoud et al., 2015) and flipped classrooms allow for active learning (Bergmann and Sams, 2012). Flipped learning has also been shown to narrow the gap for female students in undergraduate chemistry (Gross et al., 2015). However, there have been no studies in undergraduate calculus that examine the success of women and minorities in a fully flipped large section calculus environment and how the flipped environment effects the students' attitudes about mathematics and their intent to pursue Calculus II.

Existing Research

The studies that explored the impact a flipped lecture course has on subpopulations of students within a large section undergraduate Calculus I course are limited. Furthermore, there have been no studies that explore how the flipped Calculus I course may affect students' intent to pursue Calculus II. Much of the prior research on aspects of flipped classes in undergraduate calculus has been limited to small sections (Adams and Dove, 2018; Renfro, 2014; Ziegelmeier and Topaz, 2015). Adams and Dove (2018) found increased achievement on a calculus skills test, final exam and course grades, but found no difference in students' beliefs about mathematics in the flipped section. Ziegelmeier and Topaz (2015) found no performance difference between the flipped and traditional sections, but the instructor found the class to be more relaxed and less rushed. Renfro (2014) found an increase in test scores and increased scores on the ATMI (attitudes toward mathematics survey) in the flipped courses compared to historical data. None of these studies gave details about the demographics of the students nor any information about students' intent to continue onto Calculus II.

There have been examples of entire mathematics departments flipping their calculus courses (Berrett, 2012; Jungic et al., 2015; Larsen et al., 2015). Berrett (2012) found that knowledge gains increased in the flipped courses compared to traditional lecture courses at other universities. Jungic et al. (2015) noted that instructors at Simon Fraser felt that the achievement in the flipped lecture courses were improved enough that flipped classes would be the new normal at Simon Fraser. This study lacked quantitative data, but did include student and instructor experiences. Larsen et al. (2015) also reported a mostly positive instructor's experience from a private bachelors granting university. Larsen et al. (2015) noted that buy in from the instructor was important. This report did not include quantitative data or demographic information.

Sun et al. (2018) explored the role of self-regulated learning and students' success in a flipped math course. Sun et al. (2018) found that students with higher confidence performed better in the flipped class. Turra et al. (2019) found that students' attitudes toward mathematics increased after an experience in a flipped undergraduate mathematics class particularly for female students. Both McGivney-Burelle and Xue (2013) and Scott et al. (2016) experimented in flipping Calculus II. McGivney-Burelle and Xue (2013) only partially flipped small section Calculus II courses and found that students scored higher on the unit exam on the flipped section than students in the traditional section. Students noted that they enjoyed the flipped section, particularly the availability of video and class time to problem solve. Scott et al. (2016) flipped small section Calculus II courses and found that students' knowledge gains were similar to traditional classes, but the flipped class was more effective at increasing subject interest and getting students engaged. The instructors noted increased interaction in the flipped sections.

There is limited research that shows significant differences in learning as measured by test scores between flipped and traditional approaches in large section Calculus I courses. Maciejewski (2016) flipped a large section calculus for life sciences course and found that flipped students outperformed traditional students on the final exam. However, there were other factors in the class that could have caused variation in the test scores including instructor experience. This study was not a Calculus I course and did not include demographic information. The qualitative data on flipped large lecture calculus courses is limited to one set of instructor experiences as well as one study on the effect of math efficacy in students in a flipped large lecture calculus class (Jungic et al., 2015; Sun et al., 2018).

Design of the Class

In the fall of 2021, the Department of Mathematics at the University of Arkansas utilized the flipped classroom approach in a large section Calculus I course. The lecture portion of the course was predominantly replaced with video lectures watched the night before class. In the literature involving flipped courses, a common issue was the instructor's concern about whether students watched the video (Milman, 2012). To remedy this issue, the instructor of the flipped approach created videos that contained embedded quiz questions to ensure that students were watching the videos. The video could not be fast forwarded, but it could be watched on an increased playback speed. Rice et al. (2019) compared videos with quiz questions to traditional videos and found that students performed significantly better on tests when videos had embedded questions and students overwhelmingly supported the quizzes being embedded in the video. For the in-class portion of the Calculus I course, the instructor utilized the time to have students do meaningful activities to engage students in active learning and discourse. This allowed students to grapple with the mathematics while an instructor was present to guide them through difficult problems. The professor that taught the flipped section also taught the traditional section. Data from both of these courses were utilized in this study.

Methodology

To explore multiple aspects of the viability of the flipped classroom design in large section Calculus I courses, a mixed method design was utilized. This mixed methods research (MMR) design allowed for an integrated interpretation of data acquired in the qualitative and quantitative strands of the design that provided a broader perspective of what was occurring in a flipped model of instruction in contrast to a mono-method design. The rationale for conducting a MMR design was complementarity for the purpose of triangulation, specifically to obtain a broader insight into the topic of flipped large section calculus classes. Bazeley and Kemp (2012) discuss this type of triangulation in which it is used to complement instead of validate or confirm saying,

> neither method nor any source is adequate in itself to provide the necessary information, information derived from the various sources needs to be integrated during analysis and preparation of the results in order to achieve the goal, that is, all sources must be used together (p. 65).

Greene, Caracelli, and Graham (1989) define a complementarity mixed methods rationale as a study in which "qualitative and quantitative methods are used to measure overlapping, but also different facets of a phenomenon, yielding an enriched, elaborated understanding of that phenomenon (p. 258)." According to Greene, Caracelli, and Graham (1989), complementarity seeks to "increase the interpretability, meaningfulness, and validity of constructs and inquiry results by both capitalizing on inherent method strengths and counteracting inherent biases (p. 259)." The quantitative and qualitative strands in the design allowed a multifaceted understanding of the flipped classroom model. The quantitative strand explored aspects of the flipped large section calculus classes including the students' attitudes toward mathematics in both the flipped lecture and traditional courses; the students' academic achievement in both the flipped and traditional calculus courses including grades and exam scores; and the students' plans to continue in mathematics at both the beginning and end of the flipped and traditional lecture courses. The qualitative strand explored the perspective of the students and the instructor engaged in the flipped classroom model to gain insight into their experiences in the flipped classroom environment.

The first and second research questions were answered by comparing the final exam scores and the pass rates of the flipped course with the traditional courses. A logistic regression analysis was used to make the comparison on the pass rates of the students in the two classes and compare subpopulations of students and their pass rates in the course. A Mann-Whitney test was used to compare the final exam scores. To answer the third research question, Tapia's (2004) Attitudes Toward Mathematics Inventory was given at the end of the course to the students in both the traditional section and the flipped section. This survey gave insights into the students' confidence, value, enjoyment, and motivation in mathematics. This survey also included a question about the students' plans to pursue Calculus II to answer the fourth research question. Open-ended questions were added to the survey to get robust qualitative data from the flipped calculus section. These questions were analyzed with the qualitative analysis techniques from Marshall and Rossman (2016). An interview with the instructor of the flipped Calculus I course was also included as part of this analysis. The instructor interview, student survey, ATMI questionnaire, and grade data were used to answer the final research question.

Chapter 2 Literature Review

This chapter reviews the literature surrounding the challenges in undergraduate calculus programs, student choices to take mathematics, active learning, attitudes in mathematics, the advantages of flipped learning, the challenges in flipped classrooms, the perspectives of students and instructors in flipped classrooms, flipped calculus and large section course literature, and the use of video in flipped classrooms. Prior research has demonstrated that active learning has improved student learning in undergraduate calculus classes. The limitations in studies of the extended exposure to the flipped classroom model and its impact on learning will be described.

Undergraduate calculus programs face significant challenges in retaining students especially for female and minority students (Bressoud et al., 2015). Existing literature indicates that inquiry-based and active approaches have a positive impact on student outcomes and retention in STEM, especially for female and minority students (Boaler et al., 2011; Freeman et al. 2014; Laursen, Hassi, Kogan, & Weston, 2014; Rasmussen & Kwon, 2007). In recent years, the flipped lecture model has been increasingly used to enable instructors to spend more class time on active learning approaches (Bergmann and Sams, 2012). The research in flipped large section undergraduate calculus classes is limited (Jungic et al., 2015; Larsen et al., 2015; Maciejewski, 2016; Sun et al., 2018). This chapter will synthesize these studies and highlight the gaps in the literature including the impact flipped large section calculus classes have on female and minority students, retaining students who plan to continue to Calculus II, and how the flipped classroom effects the attitudes of students toward mathematics.

Challenges in Undergraduate Calculus

In 2009, the Mathematical Association of America launched a large-scale study of Characteristics of Successful Programs of College Calculus (CSPCC) (Bressoud et al. 2015). In this study, Bressoud et al. (2015) noted that, “Calculus occupies a unique position as gatekeeper to the disciplines in science, technology, engineering, and mathematics (STEM).” (p. v). According to Ellis et al. (2016), women are one and a half times more likely to be dissuaded from continuing on in calculus after taking Calculus I even when controlling for academic preparedness, career intentions, and instruction, noting a lack of self-confidence rather than achievement as a possible reason for this departure. Calculus I has repeatedly been linked to students’ decisions to leave majors in the STEM fields (Chen, 2013; Ehrenberg, 2010; Steen, 1988). According to Bressoud et al. (2015), “Success rates in calculus for women, students from underrepresented minorities, economically disadvantaged students, and first-generation college students have always been disappointing. The loss of these students is a luxury our nation cannot afford. (p. v)”

Despite consistent criticism, lecture instruction has continued to be the predominant instructional strategy in higher education (Roehl et al., 2013). According to Bressoud et al. (2015),

> our colleges and universities find themselves in the vise created by the dramatic growth in the number of incoming students hoping to pursue careers in engineering or science pressed against the drastic budget cuts that have forced departments to reduce the number of full-time faculty and to teach calculus in ever larger classes. (Bressoud et al. 2015, p v).

Schullery et al. (2011) said,

> The all-too-common phenomenon of holding introductory courses in large lecture halls raises familiar concerns: little or no interaction with the professor, limited student engagement with the material, problematic evaluation of learning, and little positive impact on retention. (p. 1).

Hornsby and Osman (2014) noted that, large lecture courses are counterproductive to developing critical thinking skills, but because of financial constraints and large numbers of students interested in STEM fields they are here to stay. Bressoud and Rasmussen (2015a) conducted a survey of undergraduate calculus courses and noted that "Calculus I, as taught in our colleges and universities, is extremely efficient at lowering student confidence, enjoyment of mathematics, and desire to continue in a field that requires further mathematics. (p. 144)".

The existing literature has pointed to the disadvantages of traditional lecture modes of instruction in Calculus I. The way Calculus I has been traditionally taught has been particularly problematic for women, minorities and economically disadvantaged students (Bressoud et al., 2015). Despite the literature, universities have been hesitant to change the instructional delivery method of these courses (Hornsby & Osman, 2014).

Students' STEM and Mathematics Choices

According to a Kaleva et al. (2019), students who chose to study mathematics believed it to be useful in their future careers and education. Seymour and Hewitt (1997) conducted a three-year study to determine factors that prompted students to leave STEM fields. They found that one of the reasons students left STEM majors was due to the negative experiences in their introductory courses, including poor teaching in mathematics and science classes (Seymour and

Hewitt, 1997). Rasmussen and Ellis (2013) conducted a study to determine why students who intend on pursuing Calculus II decide not to. The term "switchers" refers to students who intended to continue in STEM or calculus but changed their minds (Rasmussen & Ellis, 2013; Seymour & Hewitt, 1997). It was found that female students were significantly more likely to switch out of a STEM field after Calculus I, but no significant differences were found based on ethnicity (Rasmussen & Ellis, 2013). Rasmussen and Ellis (2013) found that switcher rates were significantly different for different majors. For example, they found that Engineering majors only switched at a rate of 5.9% while students in biological sciences switched at a rate of 24.8%. Several reasons were given for students who decided to switch and not take Calculus II. Thirty-nine percent of students listed changing majors as a reason they switched while 31.4% listed their calculus I experience as a reason to switch. Students also mentioned that Calculus II would take more time and effort than they wanted to spend, understanding of Calculus I not strong enough, grades, never intended to take Calculus II and that they have too many other courses to complete (Rasmussen and Ellis, 2013, pp. 460-461). Another result from Rasmussen and Ellis (2013) was that students who identified their instruction as "good teaching" and "progressive teaching" were less likely to switch. "Good teaching" included several characteristics including time to understand difficult ideas, multiple problem-solving methods, questioning techniques to ensure students understood, included applications of calculus, encouraged students to seek help, and gave assignments and graded fairly. "Progressive teaching" was defined as an environment where instructors required students to explain their thinking, work together, have class discussions, and feedback was given.

Active Learning

Freeman et al. (2014) summarized a definition of active learning from 338 written definitions in existing literature. They said that, “Active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work” (pp. 8413–8414). Existing literature indicates that inquiry-based and active learning approaches to the learning of mathematics have a positive impact on student learning, especially for women and minority students, and active learning approaches have been shown to increase retention in STEM (Boaler et al., 2011; Freeman et al. 2014; Laursen, Hassi, Kogan, & Weston, 2014; Rasmussen & Kwon, 2007). Boaler (2008) found that diverse learning activities also reduced the racial achievement gap in a study of high school students. A longitudinal study by Boaler and Staples (2008) showed that students taught using a “reform-oriented” approach learned more, enjoyed mathematics more, and progressed to higher mathematics (p. 609). According to Boaler and Staples (2008), “reformed-oriented approach” included posing long conceptual problems, group work, student presentations, teacher questioning, and teachers rarely lectured (p. 619). Prince (2013) reviewed the literature on non-traditional instructional formats and concluded that there was “broad but uneven support for the core elements of active, collaborative, cooperative and problem-based learning (p. 1)”. Shymankey & Matthews (1974) found that fifth grade science students taught under “nondirective pattern of teaching showed a greater tendency toward self-actualization” and showed significantly better investigative skills with the most dramatic difference in lower-level students (p. 167). Slavin (1980) found that cooperative learning increased achievement, self-esteem, and student collaboration.

Bonwell and Eison (1991) outlined barriers that prevent adopting active learning techniques in higher education. They identified the influence of tradition, anxiety surrounding change, limited incentives to change, available class time, preparation time, difficulty of using active learning in large classes, and the lack of resources or equipment available as factors that were prohibitive to changing traditional teaching practices (p. 7). Allen and Tanner (2017) noted that there was added difficulty in using active learning techniques in large section courses including the organizational difficulty of implementing a new instructional strategy with a large number of students as well as the time constraints involved in grading activities from a large class.

Based on their meta-analysis of 225 studies, Freeman et al. (2014) found that active learning increases exam performance and decreases student failure rates. Freeman et al. (2014) argued that the number of students receiving STEM (Science, Technology, Engineering, and Mathematics) degrees could be increased if traditional lecture was replaced by active learning pedagogies. Active learning environments have been shown to support conceptual learning gains (Kogan & Laursen, 2014), diminish the achievement gap (Kogan & Laursen, 2014), and improve STEM retention rates (Ellis et al., 2014; Seymour & Hewitt, 1997). Rasmussen et al. (2014) included active learning as one of the seven features of a successful undergraduate calculus program.

The literature suggests that active learning is a key to increasing success in calculus courses (Rasmussen et al., 2014). Active learning has been shown to improve achievement and retention in STEM (Ellis et al., 2014; Freeman et al., 2014; Kogan & Larsen, 2014; Seymour & Hewitt, 1997). The research also suggests that incorporating active-learning techniques is a challenge in large-section courses (Allen & Tanner, 2017; Bonwell & Eison, 1991). The research showcased that there is a need to discover ways to make active-learning techniques more feasible in large-lecture courses.

Attitudes in Mathematics

There is evidence that students' attitudes about mathematics effect their achievement. Research has identified links between student achievement and students' attitudes toward mathematics (Aiken, 1970; Ashcraft and Krause, 2007; Boaler, 2013; Elmore et al., 1993; Evans, 2007; Hemmings and Kay, 2010; House, 1995; Ma, 1999; Ramirez et al., 2013). When developing their attitudes towards mathematics inventory (ATMI), Tapia and Marsh (2004) defined attributes of students' attitudes toward mathematics to include their self-confidence/anxiety, the value they place on mathematics, their enjoyment of mathematics, and their motivation to pursue mathematics.

Ashcraft and Krause (2007) found a negative correlation between math anxiety and standardized math achievement on the Wide Range Achievement Test. This was consistent with the findings from Hembree's (1990) metanalysis that found math anxiety was negatively correlated with standardized test scores, high school grades, enjoyment of math, motivation in math, enjoyment of math, and the amount of high school math taken. Hemmings and Kay (2010) noted that "there is strong and consistent evidence that attitude towards mathematics and mathematical achievement are inextricably linked." (p. 44). Ramirez et al. (2013) identified statistically significant negative correlations between math anxiety and math achievement in elementary students. Ma (1999) conducted a metanalysis on attitudes, anxiety and mathematical achievement and found a significant negative correlation between negative student attitudes toward mathematics and achievement in the subject. Ma (1999) also found that reducing anxiety toward the subject could improve achievement. A regression analysis by Goolsby (1988) identified that self-confidence, SAT score, and high school GPA were predictors of success in first quarter grades in freshman developmental studies mathematics course. In a metanalysis conducted by Linn and Hyde (1989), it was found that male students had more confidence and interest in mathematics. This difference was not evident in the elementary grades, but emerged in high school. Linn and Hyde (1989) stated, “The greater confidence of males in mathematics and science may well reflect the greater representation of males in careers in these fields and no doubt serves to perpetuate the situation. (p. 23)”

Beek et al. (2017) discovered a positive correlation between the mathematics attitudes of enjoyment and low-anxiety and achievement in mathematics. A study by Thorndike-Christ (1991) determined that students who felt that mathematics was useful in their future lives were more likely to enroll in optional mathematics courses. Thorndike-Christ (1991) also found that motivation in mathematics and enjoyment of mathematics was linked to students’ decisions to take optional mathematics courses. Thorndike-Christ (1991) said, “Males expressed more confidence in their abilities to learn mathematics, reported less mathematics anxiety, and found performing mathematical tasks more enjoyable. (p. 42)”

The Flipped Classroom

Lage et al. (2000) was one of the first researchers to define what is now known as a flipped or inverted classroom: “Inverting the classroom means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa (p. 32).” Bergmann and Sams (2012) described the flipped classroom as “that which is traditionally done in class is now done at home, and that which is traditionally done as homework is now completed in class (p. 13)”. Others used more detailed descriptions of the differences between flipped and traditional approaches to instruction. According to Sun (2015),

> Grounded in active learning theory, the flipped classroom, also called an inverted classroom, is an instructional model or approach that involves moving lectures outside of the classroom, typically in the form of online lectures, and using the in-class time for engaging students in work that is associated with the application of the online materials. (p. 5)

Herreid and Schiller (2013) said,

> The flipped classroom idea is not new. Teachers have forever struggled to get students to study on their own, either ahead of time or as homework; that is when the real learning happens, not when the teacher is lecturing, droning on and on. The flipped classroom, with its use of videos that engage and focus student learning, offers us a new model for case study teaching, combining active, student-centered learning with content mastery that can be applied to solving real-world problems. (p. 65)

Sun (2015) also noted that the design of the flipped class allows instructors to push the lower cognitive content to pre-class allowing students to focus on the higher cognitive-level skills in class such as analyzing, evaluating and creating.

Flipped approaches to instruction have also been studied in content areas other than mathematics. Two high school science teachers pioneered flipped learning in 2007 and wrote a book about their experiences (Bergmann & Sams, 2012). Since then, flipped learning has become commonplace in both secondary and undergraduate education. The rigorous research surrounding flipped classrooms is still limited. There have been studies that compare traditional courses to flipped courses (Balaban et al., 2016; Day and Foley, 2006; He et al., 2018; Reyneke and Fletcher, 2014; Rossi, 2014; Sahin et al., 2015; Talley and Scherer, 2013), studies that gain insights into the student's perspective of flipped classrooms (Davies et al., 2013; Krueger & Storlie, 2015; Lage, Platt & Treglia, 2000; McCallum et al., 2015; McNally et al., 2017; Nouri, 2016; Phillips & Trainor, 2015; Rossi, 2014), components that make a flipped classroom successful (Fulton, 2012; Sun, 2015), as well as studies that assess the changes in students from the beginning of a flipped course to the end (Vaughn, 2014).

Benefits of Flipped Classrooms

Prior studies of flipped classroom instructional approaches have shown promise in terms of improving achievement. Cheng et al. (2019) conducted a meta-analysis and found that student learning outcomes were significantly improved in the flipped vs. traditional classroom. In 2009, a southern Minnesota school district flipped all of its mathematics classes and found that achievement and engagement were improved using a flipped classroom model, according to Kathleen Fulton (2012b). The teachers in the district listed the following ten reasons that it would be advantageous for teachers to conduct a flipped classroom: (1) students move at their own pace; (2) doing "homework" in class gives teachers better insight into student difficulties and learning styles; (3) teachers can customize and update the curriculum and provide it to students 24/7; (4) Students have access to multiple teachers' expertise; (5) Teachers flip professional development by watching each other's videos and learning from each other; (6) classroom time can be used more effectively and creatively; (7) Parents have a window into the coursework; (8) Increased student achievement, interest, and engagement; (9) learning theory supports the new approaches; and (7) the use of technology is flexible and appropriate for "21st century learning." Herried and Schiller (2013) interviewed 200 teachers that were utilizing a flipped classroom approach. According to those teachers, the advantages of flipped classrooms included: students have more time on authentic research and with classroom equipment, students who missed class have access to the lecture, students are more involved and enjoy the flipped classroom, and the flipped classroom promotes thinking both inside and outside the classroom. Bergman and Sams (2012) noted that a flipped classroom gives instructors time to pursue inquiry and problem-based learning in class while moving the lecture and definitions to video. Larsen et al. (2015) interviewed an instructor after flipping a class and they observed that "the online videos freed up time in class to get students to think more deeply about problems, make connections, think in a more abstract way and solve more complex problems (p. 102)." Bergmann and Sams (2012) listed the following reasons to flip a classroom: "Flipping speaks the language of today's students (p. 20)", flipping helps busy and struggling students, "flipping allows students to pause and rewind their teacher (p. 24)", "flipping increases student-teacher interaction (p. 25)", "flipping allows teachers to know their students better (p. 26)", flipping increases student-student interaction (p. 27)", "flipping allows for real differentiation (p. 28)", and "flipping is a great technique for absent teachers (p. 32)".

Several of the advantages of flipped classrooms are echoed in literature. Brunsell and Horejsi (2013) found that "flipping the classroom opens up more class time for student collaboration (p. 8)." Flipped classrooms allowed for more time for discovery and problem solving also known as active learning. This is a commonly listed advantage of the flipped classroom echoed in multiple cases in literature (Bergmann and Sams, 2012; Clark 2015; Fulton, 2012b; Gullen and Zimmerman, 2013; Milman, 2012; Zappe et al., 2009). Another common theme was that flipped classrooms allowed for student-centered instruction (Brunsell and Horejsi, 2011; Clark, 2015; Fulton, 2012b; Gullen and Zimmerman, 2013; Phillips and Trainor, 2014; Roehl et al. 2013; Vaughan, 2014; Zainuddin and Halili, 2016). Since active learning has been shown to have a positive impact on learning, the flipped model gives a path for active learning in large section courses. (Boaler et al., 2011; Freeman et al. 2014; Hassi, Kogan, & Weston, 2014; Laursen, Rasmussen & Kwon, 2007)

According to Scovotti (2016), the flipped classroom approach allows students to have access to the content at all times. Flipped classrooms allow teachers to truly differentiate instruction (Brunsell and Horejsi, 2013; Clark, 2015; Davies et al., 2013). Student involvement is also increased in the flipped classroom model (Brunsell and Horejsi, 2013; Clark, 2015; Herreid and Schiller, 2013; Vaughan, 2014; Zainuddin and Halili, 2016). Teo et al. (2014) noted reduced learning anxiety and improved efficiency in the flipped classroom. Lage et al. (2000) found that female students were more active in the inverted classroom and enjoyed the collaborative environment offered in the flipped classroom. Lage et al. (2000) also found that using a flipped approach may attract female students to fields in which they are underrepresented. The flipped model allows for real time feedback on student misconceptions (Goodwin & Miller, 2013; Gullen and Zimmerman, 2013). Increased feedback has been shown to increase achievement (Beesley & Apthorp, 2010; Hattie, 2009).

Flipped classrooms have been shown to increase test scores and academic performance (Davies et al., 2013; Fulton, 2012b; O'Flaherty & Phillips, 2015; Stone, 2012; Talley and Scherer, 2013; van Alten, 2019; Zainuddin and Halili, 2016), improved attendance (O'Flaherty & Phillips, 2015; Stone, 2012), self-paced learning (Goodwin and Miller, 2013), increased retention for African American students in STEM (Tally and Scherer, 2013), increased engagement (Bergmann and Sams, 2012; Goodwin and Miller, 2013; Tally and Scherer, 2013; Zainuddin and Halili, 2016), increased student responsibility (Bergmann and Sams 2012; Fulton 2012), and increased motivation (Zainuddin and Halili, 2016). In addition to higher attendance, results indicated positive attitudes in student evaluations, and improved exam scores; Stone

(2012) found a decrease in student drops in a flipped introductory biology course. Also, Davies et al. (2013) mentioned that flipped classrooms can accommodate large numbers of students effectively. This results in an effective alternative to large-section lecture courses. Roehl et al. (2013) adds that the flipped classroom allows for the class to move forward despite student or teacher absences (p. 47). Frydenberg (2013) flipped an introduction to Excel course and found that the flipped class improved understanding, retention of the material, and increased the satisfaction in the course.

Challenges in the Flipped Classroom

There are several challenges reported in conducting a flipped classroom. First, teachers noted that students may be resistant to flipped classrooms (Herried & Schiller, 2013; McNally et al., 2017; Phillips & Trainor, 2014; Scovotti, 2016). McNally et al. (2017) surveyed students and found that some are resistant to the flipped classroom, however it was found that there is "evidence to suggest that relying on student perceptions and satisfaction when evaluating flipped classrooms is not indicative of assessing student engagement and academic achievement and that future research in this area should attempt to measure more than student perceptions." (p. 294)

Students' lack of preparation to participate in the active learning sessions has also been found to be a challenge to flipped classroom approaches (Herried and Schiller, 2013; Milman, 2012; Phillips & Trainor, 2014; Scovotti, 2016). Milman (2012) noted that students may not watch the videos in an appropriate location for undisturbed learning. Students were unable to ask questions in real-time during the lecture portion of the flipped class (Milman, 2012; Phillips & Trainor 2014). Another challenge of the flipped classroom is the amount of responsibility put on the students (Phillips & Trainor, 2014; Scovotti, 2016). The flipped classroom trusts that students are self-motivated and responsible (Phillips & Trainor, 2014; Roehl, Reddy & Shannon, 2013). Milman (2012) noted that students may not watch the videos or may feel overwhelmed by the number or length of the videos. According to Rohel et al. (2013), “the flipped classrooms, as well as active learning, require students to assume more responsibility for their individual learning experience. (p. 48)”. This requires the instructor to set early expectations for students and their progress (Rohel et al., 2013). The adoption of the flipped classroom model can be a difficult and time-consuming task for the instructor (Herried and Schiller, 2013; Phillips and Trainor, 2014; Scovotti, 2016). Phillips and Trainor (2014) noticed that “not all students thrive in a collaborative learning environment (p. 107).” Much like a lecture course, there will be students who simply do not prefer the flipped classroom and collaborative environment.

Bull et al. (2012) said, “Because the concept is relatively new and still evolving, little research is available to guide best practices (p. 11).” Instructors who adopt the flipped classroom model are having to create a classroom model with little research available. Goodwin and Miller (2013) commented on the lack of scientific research in the flipped classroom field, “The lack of hard scientific evidence doesn’t mean teachers should not flip their classrooms; indeed, if we only implemented strategies supported by decades of research, we’d never try anything new. (p. 78)”

Student perceptions of flipped classrooms

Studies on students’ perceptions towards flipped classrooms have been generally positive (Davies et al., 2013; Krueger & Storlie, 2015; Lage, Platt & Treglia, 2000; McCallum et al., 2015; Nouri, 2016; Phillips & Trainor, 2015). In the economics course that was flipped by Lage et al. (2000), the majority of students were “favorably impressed by the course (p. 35).” However, Scovotti (2016) found that students had mixed feelings in a study of students’ perceptions in a marketing capstone course. Common complaints were that the out-of-class workload was too much and that the instructor wasn't teaching. Other students enjoyed the ability to watch videos and work at their own pace. McCallum et al. (2015) found that students in the flipped classroom liked being able to watch the video lectures and pause when needed. McCallum et al. (2015) also found that students felt more prepared for class, felt more engaged, appreciated in-class feedback, appreciated in-class cooperation, found the instructor more accessible and appreciated being in control of the pace. However, students noted that they struggled with the self-discipline and responsibility in the flipped classroom

Nouri (2016) surveyed 240 students in a flipped learning environment and found that the "a large majority of the students had a positive attitude toward flipped classroom" and that positive attitude "was strongly correlated to perceptions of increased motivation, engagement, increased learning, and effective learning (p. 1)". This was especially true for low achievers. Pierce and Fox (2012) found around 80% of students' self-efficacy improved in the flipped classroom model and the majority of students had a positive view of the flipped class. In an introductory business course, Schullery et al. (2011) found that students felt a high level of engagement in a flipped classroom, were motivated to attend class, and enjoyed the classroom interaction. Phillips and Trainor (2014) discovered that millennial students enjoyed the technology and were engaged in the flipped classroom model. O'Flaherty & Phillips (2015) found that students in the flipped classroom model had positive feedback about the opportunities for developing communication skills, working in teams, and active engagement. However, according to O'Flaherty & Phillips (2015), "the same students, despite an improvement in student grades, found that students were quite negative towards the introduction of the flipped class. (p. 89)".

Instructor's perspectives of flipped classrooms

Lage et al. (2000) found that instructors favored the use of flipped classrooms noting an increase in student engagement. Clark (2015) found that

> students were more engaged, more involved in the flipped model of instruction when compared to the traditional delivery approach. Students in the flipped classroom experienced quality instruction that was student-centered and student-focused. The flipped classroom allowed for improved use of class time utilizing various instructional strategies, including hands-on activities and project-based learning structures. (p. 112)

Brunsell and Horejsi (2013) reported that teachers show improved job satisfaction when using a flipped classroom approach. However, the flipped experience for instructors was not all positive especially in the beginning. Scovotti (2016) found that

> From the instructor's perspective, redesigning the course was difficult and time consuming. Lecture pieces had to be able to stand alone as well as work together with the rest of each module's content. Writing and vetting hundreds of module quiz questions was especially time consuming. However, the up-front instructor preparation time made reuse easy and fast for subsequent semesters. The instructor also noted that she was able to reduce the amount of time needed for preclass preparation throughout the semester. (p. 55).

Similar to students' views on flipped classrooms, instructors experience the most hesitancy in the implementation phase.

Long et al. (2017) conducted a qualitative study to gain insights into the perspective of instructors that were engaged in a flipped classroom model. According to Long et al. (2017), instructors perceived that to make a flipped course effective the instructor must "ensure students have prepared prior to class (p. 145)", be well organized in instruction (p. 146)", "think as students (p. 147)", and provide instant support in class (p. 147)". The perceived challenges that Long et al. (2017) found from the interviewed instructors were that instructors had to motivate and ensure students learned before class, not all students enjoy active learning, students must be encouraged to collaborate, the time investment is huge, and instructors felt the need for support.

Research in Undergraduate Flipped Classrooms

There are several examples in literature of flipped large section undergraduate courses in various subjects. He et al. (2018) partially flipped (some lecture components remained in the course) a large section chemistry course and found that the flipped course had a positive effect on student grades and subsequent course performance especially for students with lower high school GPAs. There was no difference in final exam scores, but the researcher concluded that the students in the flipped course showed higher motivation especially in the academically weaker students. This study only experimented with a partially flipped environment and was a chemistry course instead of calculus.

Balaban et al. (2016) researched a flipped large section principles of economics course. The researchers found that the flipped classroom improved final exam performance by .2 to .7 standard deviations. It was found that the flipped classroom did not impact performance on basic knowledge questions, but significantly improved performance on comprehension questions that required understanding, interpreting, comparing, and explaining. The researchers concluded that the effect of the flipped classroom came from the active learning that accompanies the flipped classroom.

Gross et al. (2015) examined the effect of flipping a physical chemistry course catering toward life science majors. This study found that exam performance significantly improved in the flipped course by nearly 12%. It was found that the most pronounced effects were for female students and students with lower GPAs. It was found that in the traditional courses, female students were consistently four to five percentage points lower than male students on the exams. However, in the flipped course there was no significant difference in scores by gender on two of the three exams.

Undergraduate Calculus Courses

Several studies of flipped undergraduate calculus classrooms can be found in recent literature. According to an article by Berrett (2012), the University of Michigan at Ann Arbor has been flipping its calculus courses since the mid-1990s. The faculty received intense training in how to conduct a flipped calculus course. According to Berrett (2012), these courses have shown greater conceptual understanding. In 2008, the students were given a concept inventory test and Michigan's flipped courses showed gains at about twice the rate of those in traditional lectures at other institutions. This study has not been published outside of Berrett's (2012) article and though the results show promise, there is a need for a more rigorous consideration of the academic gains in flipped undergraduate calculus courses.

McGivney-Burelle and Xue (2013) flipped a section of the material on Integration in an undergraduate Calculus II course at the University of Hartford, a midsized private university in the Northeast. The courses were each 25-30 students. The students viewed short videos that summarized the key lesson concepts before class. Students in the flipped course scored higher on the unit exam than the students in the traditional course. McGivney-Burelle and Xue (2013) came to the conclusion that

> Overall, there was enough evidence to indicate that our flipping pedagogy in calculus was effective and worth the significant investment of faculty time and effort. Students in the flipped section of the course preferred this type of pedagogy, particularly the availability of videos and the use of class time to solve problems, and fared better on homework and tests. (p. 485)

This study indicates that the flipped pedagogy works for a section of material in a small section Calculus II course. The limitations of this study are that the class size was small and only a section of material was flipped. The pedagogical effect on women and minority students was not included as a part of the study as well as whether or not the flipped approach influenced students' intent to continue in mathematics.

Scott et al. (2016) also experimented in flipping Calculus II. One-hundred students enrolled in four Calculus II sections. It was noted that a larger portion of female students enrolled in the flipped sections, even though students did not know at enrollment that the courses would be taught differently. Scott et al. (2016) found that knowledge gains in a flipped second semester calculus course were similar to the lecture-based course, but that the flipped class was more effective at increasing subject interest and getting students to discuss and problem solve. The instructors of the four courses were also interviewed to gain insight into their classroom experience. Both instructors reported that the flipped class increased interaction in the classroom. This study again examines small section Calculus II courses. There was again no indication of how the pedagogy effected women and minority students or the students' intent to continue in mathematics. This was not a large section course and was not Calculus I.

Adams and Dove (2018) conducted an experimental study comparing a small section flipped undergraduate calculus course with a traditional small section undergraduate calculus course at a mid-Atlantic university of around 10,000 students. A small sample size of 19 students from each course type was evaluated. Adams and Dove (2018) found that achievement on a calculus skills pre/posttest, final exam scores, and final course grades substantially improved in the flipped section compared to the traditional section. Adams and Dove (2018) found no difference in students' beliefs about learning mathematics in the traditional and flipped calculus sections. These results were opposite of the results from the study by Scott et al. (2016). The biggest limitation of the study by Adams and Dove (2018) was the small sample size. Again, no mention was made of demographic information or the impact on students' future plans in mathematics.

Ziegelmeier and Topaz (2015) conducted a controlled flipped classroom experiment at a small liberal arts college. They compared two applied multivariable Calculus I courses taught by the same instructor, one flipped and one traditional. The sections were back-to-back and students were not informed of the pedagogical method prior to enrolling. The two courses had 23 and 22 students enrolled. No significant difference was found in the performance between the two classes. The instructor felt that the flipped class was more relaxed and less rushed. This study was a very small sample size and conducted at a selective private university. The study did not include any information about the demographic breakdown for the students in the courses nor the impact of the flipped model on the students' intent to take further mathematics courses.

Renfro (2014) flipped an undergraduate Calculus I course at Robert Morris University in an action research analysis where the researcher was the instructor. It was found that students generally viewed the flipped class favorably, students reported a positive impact on their mathematical ability, students found value in the social learning of the class, and students found value in the videos that were available. The mean scores on the final exam increased in the flipped section and the final exam data was more homogeneous in the flipped course than the traditional course. Renfro (2014) concluded that "The flipped classroom and its corresponding benefits may have leveled the playing field to some extent by bringing overall student understanding of the material closer to the center (i.e. reducing the standard deviation, while raising the mean slightly) (p. 361)." Renfro's (2014) action research study found that the students in the flipped courses scored higher on the ATMI (attitudes toward mathematics inventory) in all four domains including self-confidence, value, enjoyment, and motivation. Renfro (2014) found that though most students benefited from the flipped learning environment, a few students expressed that they felt overwhelmed in the flipped classroom model and preferred direct instruction. Some limitations of Renfro's (2014) study were that the researcher was the instructor allowing for bias. Also, there was no control section in which to compare the flipped classroom environment. The flipped classroom final exam scores and pass rates were compared to historical data. The interviewer was the instructor which could cause the students to be less than forthcoming about the classroom experience. The instructor mentioned several differences in his instructional style not related to the flipped classroom that were included in this study. This creates a possible set of confounding variables into the study. The study was conducted over multiple semesters with the ATMI being given in the next calculus course. This could lead to other factors causing changes in the students' attitudes about mathematics. Renfro's (2014) class was a class of 30 students which would be considered a small section calculus course. This is a small sample size leading to limited statistical power in the study. No details about demographics of the students were included in the study as well as no mention of the effect the flipped classroom had on students' intent to continue in mathematics.

Sahin (2015) conducted a study of flipped Calculus I and Calculus II courses for engineers. There were 79 male students and 17 female students in ten courses. Three were flipped and seven traditional. It was found that students preferred videos to reading the textbook, quiz scores were significantly higher, students felt better prepared, and students had higher motivation in the flipped calculus course (Sahin et al., 2015). Sahin et al. (2015) also found that students had improved levels of understanding and higher levels of self-efficacy. The research seems to indicate that flipped courses particularly in undergraduate Calculus I are an improvement over the traditional lecture courses. There were several limitations to the study. First the study included predominately male students. This study did not include demographic information in the results or the effect of the flipped classroom on students' intent to pursue further mathematics. This was not a large-section calculus course and it is unknown which courses were Calculus I and which ones were Calculus II.

Turra et al. (2019) conducted a study on the flipped classroom model and students' attitudes toward university-level mathematics for Chilean Engineering students. 76 Calculus I, II, and III students were given an Attitudes Towards Mathematics questionnaire before and after a flipped classroom experience. The results showed a positive change in attitudes toward mathematics especially for students from lower income families. The results also showed a significance in the post test results for female students on the questionnaire. This study had several limitations. The study did not have a control group, provide academic data or provide qualitative data. This study was conducted on students in Chile on a small sample of students in various mathematics courses.

Larsen et al. (2015) reported on a flipped classroom experiment in calculus at a private bachelors granting university, flipping all calculus courses, and discovered that, "One instructor observed that moving the exposition about definitions and procedures to the online videos freed up time in class to get students "to think more deeply about problems, make connections, think in a more abstract way and solve more complex problems (p. 102)." The researcher noted that the biggest factor in student's perception of the flipped classroom was the amount of buy in from the instructor. This report did not include quantitative data or demographic information.

Flipped Large Section Calculus Courses

Sun et al. (2018) conducted a study on flipped undergraduate Calculus I and Calculus II courses at a large Midwestern university and examined the role of self-regulated learning and students' success in the flipped math course. The Calculus I and II courses were both large lecture courses consisting of approximately 300 students in each course. The lower cognitive level material was moved to pre-class instruction and the higher cognitive level material was delivered in the in-class setting. Two online surveys were given to 151 of the students. Sun et al. (2018) found that students with higher confidence in math achieved more in the flipped class, student's prior knowledge had a direct impact on their confidence, and students who were more likely to seek help performed better in a flipped math class. Overall, Sun et al. (2018) found a significant positive correlation between students' self-efficacy and student achievement in the flipped calculus environment and suggested instructors in flipped math courses pay careful attention to tasks that improve student efficacy. Sun et al. (2018) suggested that

> To effectively design the pre-class and in-class activities in the context of flipped math classrooms, instructors must consider the relations of the identified maladaptive factors with achievement, enact appropriate strategies to support students' self-regulated learning and, ultimately, guide them to succeed. (p. 50)

Limitations to this study include the self-reported data from students and the lack of a control group. This study also did not include demographic information in the results or the effect the flipped classroom had on students' intent to continue in mathematics.

A group of professors at Simon Fraser University flipped some topics in a large section Calculus for Science and Engineering Students course. The professors at Simon Fraser noted that "After using this implementation of the flipped classroom model we can emphatically say that this is our new norm. We feel more engaged with our large classes (Jungic et al., 2015)." Though the instructors felt that the flipped class was more engaging, they noted the need for more empirical evidence to support improved academic achievement. On a student survey, students reported that they felt that the video lectures better prepared them for class. The study considered the impact of flipped learning on the students' experience and the experience of the instructor. The limitations of this study include the lack of quantitative data and the partially flipped atmosphere. This study did include large section calculus courses, but did not include demographic data or the impact of flipped learning on students' decision to continue in mathematics.

Maciejewski (2016) flipped a large calculus for life sciences course at a research-intensive Canadian university. Maciejewski (2016) found that the students in the flipped course outperformed the traditional student on the final exam by 8%. It was found that students with good basic skills and low calculus knowledge benefitted most from the flipped classroom model. This study included a large data set and compared scores on a calculus concept inventory, a mathematics attitudes survey, and a basic skills test. Some limitations of this study are that the instructors of the control group were less experienced than the instructors of the flipped courses. Though this study did discuss student differences in ability level, it did not consider gender and race as it connects to success in the flipped classroom. This study did not include qualitative data.

Though there has been research on several aspects of flipped classes in undergraduate calculus, there have been no rigorous studies that explore the impact a flipped lecture course has on subpopulations of students within a large section undergraduate Calculus I course. There have also been no studies that explore how the flipped Calculus I course may affect students' intent to pursue Calculus II, particularly in a large section environment.

Video

There is widespread literature on the effect of providing students with instructional videos. Instructional videos and video podcasts have been shown to have a positive impact on student attitudes (Bolliger et al., 2010; Fernandez et al., 2009; Hill & Nelson, 2011; Holbrook & Dupont, 2011; Kay, 2012) and student achievement (Alpay & Gulati, 2010; Boster et al., 2006; He et al., 2012; Kay, 2012; Traphagan et al., 2010). Kay (2012) found in a comprehensive review of literature on video podcasts that other benefits included control over learning and improved study habits. Kay (2012) found the challenges of video included technical problems, some student preference for lecture, and reduced class attendance. Traphagan et al. (2010) found that webcasts have positive effects on students' learning even when taking into account a drop in attendance. He et al. (2012) found that online video tutorials are a valuable, flexible, and cost-effective tool for improving student mastery in difficult chemistry problems, particularly for struggling students. Rice et al. (2019) compared videos with quiz questions to traditional videos and found that students performed significantly better on tests when videos had embedded questions and students overwhelmingly supported the quizzes being embedded in the video. Van Alten (2019) found that flipped classrooms were more successful when quizzes were implemented as a part of the class. Much of the research on videos is applicable to flipped classrooms. In Frydenberg's (2013) introduction to excel classes, he found that the "key to this implementation to the flipped classroom were the screencasts to be watched the day before class, the quizzes which provided an incentive for watching them, and the in-class exercises and debriefing time (p. 70)."

In video creation, Moreno et al. (2020) noted that pedagogy is more important than technical video knowledge in creating quality videos. Aaron Sams and Jonathan Bergmann (2015) noted that students are more comfortable with videos when they have a relationship with the creator. They said, **"**When we visit struggling flipped classrooms, we often see that the teacher is simply assigning video content created either commercially or by teachers outside their immediate network rather than making their own. Conversely, when we walk into successful flipped classrooms, we usually find that the teacher is the video creator. (p. 13)"

Summary

Bressoud and Rasmussen (2015a) noted seven characteristics that lead to successful calculus programs. The list included attention to the effectiveness of placement procedures, proactive student support services, construction of challenging and engaging courses, use of student-centered pedagogies and active-learning strategies, coordination of instruction (including the building of communities of practice), effective training of graduate assistants, and regular use of local data to guide curricular and structural modifications. Educators and researchers have long questioned the effectiveness of lecture-based courses and have longed for a shift toward a more learner-centered structure (Bar and Tagg, 1995). Rasmussen and Ellis (2013) defined "Progressive" teaching as "instructional approaches that more actively engages students" (p. 462). They found that students who originally planned to go on to Calculus II are more likely to persist when instructors have used progressive instruction. One form of progressive instruction is utilizing the flipped classroom environment to increase active learning activities in Calculus I courses.

In this review of the literature on the challenges in undergraduate calculus programs and flipped classrooms, it appears that flipped classrooms may be a solution to the existing problems plaguing universities' calculus programs. Flipped classrooms have shown promise in multiple disciplines including undergraduate calculus and in large section courses. Flipped classrooms have been shown to improve student attitudes toward mathematics which in turn improves achievement. Though studies have been conducted in flipped undergraduate calculus courses, there is still much to learn. Active learning has been tied to increases in calculus success for women and minority students (Bressoud et. al, 2015) and flipped classrooms allow for active learning. Flipped learning has also been shown to narrow the gap for female students in undergraduate chemistry (Gross et al., 2015). However, there have been no undergraduate calculus studies that examine the success of women and minorities in a flipped large section calculus environment. There have only been limited studies on the effectiveness of flipped large-section Calculus I courses in general. There have been no studies that include the impact of flipped Calculus I courses on the students' intent to further pursue mathematics or STEM related fields. Though flipped classrooms are not without their challenges, the literature shows promise that flipped classrooms may be a feasible solution to successfully improving large section undergraduate calculus courses by allowing for the student-centered learning that has been shown to increase STEM retention and success, particularly for women and minority students (Boaler et al., 2011; Freeman et al. 2014; Laursen, Hassi, Kogan, & Weston, 2014; Rasmussen & Kwon, 2007).

Chapter 3 Methodology

This chapter describes the research methods and rationale used to complete the data collection and analysis in this study. A detailed discussion of the philosophical background of the chosen methodology, data research design, instrumentation, classroom settings, participant demographics, and sampling techniques is provided. The analysis techniques used to analyze the data will also be discussed.

Research Design

Rationale and Purpose

To explore multiple aspects of the viability of the flipped classroom design in large section calculus courses, a mixed method design was utilized. This mixed methods research (MMR) design allowed an integrated interpretation of data acquired in the qualitative and quantitative strands of the design that provided a broader perspective of what is occurring in a flipped model of instruction in contrast to a mono-method design. The rationale for conducting a MMR design was complementarity for the purpose of triangulation, specifically to obtain a broader insight into the topic of flipped large section calculus classes. Bazeley and Kemp (2012) discuss this type of triangulation in which it is used to complement instead of validate or confirm saying, "neither method nor any source is adequate in itself to provide the necessary information, information derived from the various sources needs to be integrated during analysis and preparation of the results in order to achieve the goal, that is, all sources must be used together. (p. 65)". Greene, Caracelli, and Graham (1989) define a complementarity mixed methods rationale as a study in which

> qualitative and quantitative methods are used to measure overlapping, but also different facets of a phenomenon, yielding an enriched, elaborated understanding of that phenomenon (p. 258).

According to Greene, Caracelli, and Graham (1989), complementarity seeks to "increase the interpretability, meaningfulness, and validity of constructs and inquiry results by both capitalizing on inherent method strengths and counteracting inherent biases" (p. 259). The quantitative and qualitative strands in the design allowed a multifaceted understanding of the flipped classroom model. The quantitative strand explored multiple aspects of the flipped large lecture calculus classroom including the students' attitudes toward mathematics at both the beginning and end of the flipped lecture and traditional courses; the students' academic achievement in both the flipped and traditional calculus courses including grades and exam scores; and the students' plans to continue in mathematics at both the beginning and end of the flipped and traditional lecture courses. The qualitative strand explored the perspective of the students and the instructor engaged in the flipped classroom model to gain insight into their experiences in the flipped classroom environment.

Research Questions and Hypotheses

The following questions were answered by this study:

1. What was the difference in final exam scores between students enrolled in a traditional large lecture calculus class and students enrolled in a flipped large section calculus class? (Quantitative)
2. How were pass rates of subpopulations (minority status, college of study and gender) of students different for students enrolled in a traditional large lecture calculus course and students enrolled in a flipped large section calculus course? (Quantitative)

3. How did the attitudes of students toward mathematics in the flipped lecture course compare to students in the traditional lecture course? (Quantitative)
4. How did the flipped classroom model affect students' plans to pursue Calculus II? (Integrated)
5. What were the benefits and challenges of flipped large lecture calculus courses? (Integrated)

The hypotheses were that students would perform better on the final exam, have better outcomes in the course, have better attitudes towards mathematics and that underrepresented subpopulations of students in mathematics would perform better in the flipped style classroom. It was also expected that students would explain the benefits and challenges within a flipped style classroom that are consistent with existing literature.

Design

The research design was a concurrent MMR design incorporating both quantitative and qualitative strands in two different sections of a semester long Calculus I course. Equal weight was placed on the quantitative and qualitative strands. Defined by Plano-Clark and Ivankova (2016), this means that both types of data played an equally important role in answering the study's research questions. The timing of the study was concurrent as defined by Plano-Clark and Ivankova (2016), meaning that both qualitative and quantitative data were analyzed independent from each other at the same time. The integration of the data occurred after the analysis of both the quantitative and qualitative strands were completed as suggested by Plano-Clark and Ivankova (2016). This study sought to determine if the flipped classroom approach was beneficial for students in large section Calculus I courses. According to Plano-Clark and Ivankova (2016), using mixed methods research enabled the researcher to "address the research problem more fully (p. 6)" and capitalize on the strengths of each quantitative and qualitative method, producing "stronger and more credible studies that can yield both complementary and corroborating evidence about the research problem of interest (p. 9)". A pragmatic paradigm approach fit this study. According to Kivunja and Kuyini (2007),

> theorists looked for approaches to research that could be more practical and pluralistic approaches that could allow a combination of methods that in conjunction could shed light on the actual actual behaviour of participants, the beliefs that stand behind those behaviours and the consequences that are likely to follow from different behaviours (p. 35).

The framework and analysis of data was considered methodologically pragmatic. According to Creswell and Poth (2018), the pragmatic approach

> will use multiple methods of data collection to best answer the research question, will employ multiple sources of data collection, will focus on the practical implications of the research, and will emphasize the importance of conducting research that best addresses the research problem (p. 27)

The pragmatic approach allowed the researcher to explore the problem that undergraduate large section calculus courses needed improvement, especially for women and minority students (Bressoud et al., 2015).

Participants and Setting

Role of the Researcher

The researcher was an observer in this study. The instructor of record in the two courses was a former professor of the researcher. The researcher discussed the flipped style classroom with the professor, but was not involved in the day-to-day decision making in the classrooms. The researcher attended the two class sections once a week during the semester and kept a journal. The researcher had previous experience as an instructor of a flipped high school calculus course.

Sampling Design and Setting

The sample design that was used to explore the flipped large section calculus course was a non-random purposive design. The mixed methods sampling design was a concurrent multilevel design as defined by Onwuegbuzie and Collins (2007). A single instructor at a large public university conducted two Calculus I courses. Both the instructor and students from these two courses participated in the study. Both courses were large section courses originally with a cap of 148 students, and both courses were offered Monday, Wednesday, and Friday morning for 50 minutes per day. One of the courses was flipped and the other course was traditionally taught. Other than the lecture, the courses were kept as close to the same as possible. Students were given the same assignments and tests. Students signed up for courses and were able to choose the class time and instructor. There was no designation of flipped or traditional on the course description at sign up. However, the instructor was forthcoming and informed the students that they were in a flipped course at the beginning of the semester. Because of the way students enrolled in courses at the University of Arkansas, there was no way to ensure a random assignment of students in the different sections. According to Gamst, Meyers, and Gurino (2008), “the larger the sample size, the greater will be our statistical power.” All students in the participating instructor’s Calculus I courses were included in the data set for the quantitative strand to ensure a suitably large sample size to conduct a regression analysis. During the first week of classes there were 144 students enrolled in the flipped lecture course and 169 students enrolled in the traditional lecture course. The qualitative strand of the data was a nested sample including students that are also involved in the quantitative sample. The qualitative sample included all students who responded to the survey questions. The instructor interview was an opportunity sample. The instructor was chosen for his willingness to teach both a flipped and traditional lecture course.

Traditional Lecture Course Description

At the time of this study, Calculus I courses at the University of Arkansas shared common lecture slides, exams, quizzes, weekly homework assignments, and a final exam. The courses were fairly standardized across the multiple sections. Both sections used in this study met three times a week in lecture and two times a week in drill, with each meeting being 50 minutes in duration. The drill portion consisted of course coordinator-created drill worksheets, going over problems, and taking weekly quizzes, and was led by a graduate level teacher’s assistant. The traditional lecture course that served as the control group for this experiment met on Monday, Wednesday, and Friday at 9:40 a.m. and had 169 students enrolled in this section. The primary mode of instruction in this course was lecture. The instructor did occasional exercises with the students embedded in the lecture, where students worked a problem and compared results with their peers sitting near them in the large auditorium setting. In each class, the professor included a clicker question toward the end of the lecture. In terms of overall assignments, the students had weekly homework on the MyMathLab platform that was due on Sunday nights, with these assignments contributed towards 10% of their final course grade. There were four hourly exams (each worth 12% of student's final grade) and weekly quizzes worth 15% of their grade. There was also an Attendance & Participation portion of the final grade worth 5%, which consisted of attendance for lecture and drill as well as correctly answering the daily multiple choice clicker question. The final exam was worth 22% of the course grade. The class had four graduate assistants that were available to answer questions during the lecture portion of the class.

Flipped Lecture Course Description

To maintain a quasi-experimental design, the standardized portions of the Calculus I courses at the University of Arkansas were retained in the flipped lecture course. The flipped lecture course met three times a week on Monday, Wednesday, and Friday at 10:45 a.m. The class was 50 minutes and there were 144 students in this course. The students were given a video assignment the day before each MWF class, which was generally around 20 minutes in length. There was a quiz question embedded at the end of the video that was unique to the flipped lecture course and that counted towards the student's Attendance & Participation portion of their final grade. Students were not able to fast forward through the video but could watch the video on a faster speed. Watching the short video and answering the quiz question was due by class time each day. The video consisted of a condensed version of what the traditional class experienced in lecture, including the common slides that are shared by all of the Calculus I courses at the University of Arkansas. In class, the flipped section worked problems that extended the video lecture and the lecture slides used in the traditional class. These problems were often more in depth than what the traditional class worked on in class. The students in the traditional course did not work through these problems in class, which were typically pulled from the MyMathLab set of homework questions for that specific section. This offered students more practice on problems that required higher order thinking and problem-solving skills. The professor and one graduate assistant were available to answer questions during the flipped lecture course. All of the assignments, exams and quizzes were identical to the traditional course apart from the questions worked in class, the video and the question at the end of the video. Similar to the traditional lecture section, the flipped lecture course also had a drill component that consisted of a smaller set of students led by a graduate assistant. Both the traditional course and flipped course that were being studied were taught by the same professor and kept as similar as possible except for the flipped design.

Demographic Information of the Participants

Two courses at the University of Arkansas were observed. One was the control group which will be referred to as the traditional lecture course. The other was the treatment group that will be referred to as the flipped lecture course. Both courses were self-selected by students using the University of Arkansas system for signing up for classes. At the time of selection, students did not know the lecture style of the class, so this was a blind selection. Both classes listed a maximum of 150 students. The traditional course was held in a slightly larger room allowing the university to go over the 150-student maximum. Therefore, the traditional course ended up with 169 students while the flipped course had 144 students at the first week enrollment check. From the University of Arkansas database, the students' classification, degree, ACT Composite score, ACT Mathematics score, gender, race, and first-generation status were collected. See Table 1 for a summary of the demographic information for each of the two courses.

Table 1

Demographic Information

	Flipped (*n* =144)	(%)	Traditional (*n* = 169)	(%)	Total (*n* = 313)	(%)
Sex						
Female	47	32.6	71	42.0	118	37.7
Male	97	67.4	98	58.0	195	62.3
Race						
Caucasian	100	69.4	123	72.8	223	71.2
African American	3	2.1	8	4.7	11	3.5
Asian	6	4.2	1	0.6	7	2.2
Hispanic	16	11.1	13	7.7	29	9.3
Non-Resident Alien	0	0	4	2.4	4	1.3
Two or More Races	12	8.3	7	4.1	19	6.1
Unknown	6	4.2	11	3.5	17	5.4
College						
Engineering	87	60.4	111	65.7	198	63.3
Arts/Sciences	51	35.4	44	26.0	95	30.4
Business	4	2.8	8	4.7	12	3.8
Other	2	1.4	6	3.6	8	2.6
Classification						
Freshman	102	71.3	93	55.4	195	62.7
Sophomore	27	18.9	47	28.0	74	23.8
Junior	9	6.3	19	11.3	28	9.0
Senior/Unknown	6	4.2	10	5.9	16	5.1
First Generation Status						
Yes	25	17.4	31	18.3	235	75.1
No	112	77.8	123	72.8	56	17.9
Unknown	7	4.9	15	8.9	22	7.0

The two classes had similar demographics. Both courses had a higher percentage of male students with 67.4% of participants in the flipped course and 58% of the participants in the traditional course being male. Both courses had large populations of Caucasian students with 69.4% in the flipped course and 72.8% in the traditional course. Both courses were predominantly students from the college of Engineering at the University of Arkansas. The second most common college for participants from both classes was the Fulbright College of Arts and Sciences as seen in Table 1. Freshman made up 71.3% of the participants in the flipped course, but only 55.4% of the participants in the traditional course. Only a small percent of the participants in the two courses identified as a first-generation college student, defined to be the first person in their immediate family to attend college, with 17.4% of the flipped classroom participants and 18.3% of the traditional classroom participants identifying as first-generation students. More detail about the demographic information of the two classes can be found in Table 1.

Instrumentation

Quantitative Instrumentation

Multiple quantitative data collection instruments were utilized. First, ACT scores, college affiliation, major, gender, race, first-generation status and classification were pulled from records at the University of Arkansas. Next, scores on the Calculus Concept Readiness (CCR) exam were collected from the professor of the two courses and stored in a Microsoft Excel File (Carlson, Madison, & West, 2010). Other data items collected from the professor of the courses included exam scores, homework and participation scores, quiz averages, homework averages, final exam scores, final grades, and clicker score averages. These were stored in an excel file with identifiers removed once the data was compiled. There was a questionnaire at the end of semester that included an existing Likert formatted scale, the Attitudes Toward Mathematics Inventory from Maria Tapia (2004) that collects data about student attitudes as well as a question asking about students' intent to take Calculus II.

ACT. According to the ACT Technical Manual (2020), the American College Testing is a standardized exam often used for college admission. The ACT contains a multiple-choice reading, English, science, and mathematics portion. Each scale is scored from 1 to 36. The composite score and the mathematics score were collected to compare the students in the two classes. The ACT is highly standardized, highly correlated with freshman grade point average, and has long been considered a predictor of student success in college (Lenning, 1975). Both the ACT mathematics subscale score and the ACT composite score were collected to compare student types in the two classes.

CCR. The Calculus Concept Readiness (CCR) instrument was developed as a tool to predict the success of students in calculus based on the students precalculus understandings (Carlson, Madison, & West, 2010). The CCR is a 25-question multiple choice instrument that is correlated with success in Calculus I according to Carlson, Madison, & West (2010) with a correlation of 0.51. The CCR was given to the students in both classes as an unofficial pretest for students to gauge their calculus readiness.

Grades. Grades from both classes were collected from the professor of the two classes. The professor provided final letter grades, final exam scores, and composite scores on the grade subcategories. The exam grades in the two classes were calculated using the same rubrics that are standard university wide. All University of Arkansas Calculus I exams were graded by graduate assistants and instructors that were not all involved with the research study. Homework was graded through an automated online homework system. This ensured there was no grading bias in the two classes. The two courses overall grade calculations were identical and can be found in the description of the two classes. The only difference in grades in the two classes was the inclusion of the video quiz as a portion of the grade for the flipped classroom students included in their attendance and participation sub category. Clicker score averages were also collected from a multiple-choice clicker question that was given each day in both classes. The question in the two classes was the same and was designed to check for understanding of each day's lesson.

ATMI. The Likert- formatted scale survey used Tapia's (2004) Attitudes Toward Mathematics Inventory. This survey gave insights into the students' confidence, value, enjoyment, and motivation in mathematics (Tapia and Marsh, 2004). The way a student feels about mathematics affects their success (Ashcraft and Krause, 2007; Hemmings and Kay, 2010). This gave the researcher insight into the way the flipped classroom experience affects students' attitudes toward mathematics.

Tapia's (2004) scale has been validated and content validity has been established. It is intended for high school and college students. The Attitudes Towards Mathematics Inventory (ATMI) was designed by Martha Tapia in 1996 to assess the attitudes of students about mathematics. The original inventory was given to high school students and had 49 items that assessed confidence, anxiety, value, enjoyment, motivation, and parent/teacher expectations (Tapia & Marsh, 2004). Responses were collected using a Likert-scale format with the following choices: (1) strongly disagree, (2) disagree, (3) neutral, (4) agree, and (5) strongly agree. According to Tapia & Marsh (2004), "Twelve items were reversed" and "the score was the sum of the ratings". According to Tapia and Marsh (2004), the 49 items produced a Cronbach's alpha of .96, and 40 of the items had correlations above .50. The inventory was then revised to include 40 items with four factors including self-confidence (15 items), value (10 items), enjoyment (10 items), and motivation (5 items) with a Cronbach's alpha of .95, .89, .89, and .88 respectively with a .97 overall indicating a high level of reliability (Tapia and Marsh, 2004). The 40-item inventory is estimated to take between 10 and 20 minutes to complete (Tapia & Marsh, 2004). A university population including calculus students has been studied using the ATMI. Tapia and Marsh (2003) conducted a study to examine gender differences in mathematics attitudes in undergraduate students enrolled in precalculus, calculus, and Business Calculus courses at both a large state university and a small private liberal arts college. The students included 275 undergraduate students with approximately 87% Caucasian and 11% African American. According to Marsh and Tapia (2003), the Cronbach alpha coefficients for this study were .96, .91, .90, and .88 respectively indicating a high level of reliability in this population. Gender differences in the mathematics attitudes inventory were not found in this population (Marsh and Tapia, 2003). When creating the online format of the questionnaire, one of the questions on the self-confidence scale was inadvertently left off. This item was the 10^{th} item on the self-confidence scale. The two online questionnaires were given to the participants by the professor of the two courses. The questions from these surveys can be found in Appendix 1.

Qualitative Instrumentation

Qualitative data was collected through observation, interview, journaling, and an online questionnaire. Both the professor and the researcher kept journals of information throughout the semester. Next, an open-ended questionnaire was given at the end of the semester in both the control and treatment groups. This survey contained questions about the students' intent to take Calculus II as well as their preference toward the flipped classroom. The survey given to the treatment group contained open-ended questions designed to understand the students' experience in the flipped classroom. These surveys can be found in Appendix 1. The instructor kept a journal documenting the course structure, instructional techniques, student interactions, and other notable observations. A semi-structured interview with the instructor at the midterm and end of the term was the last piece of data collection. Classroom observations by the researcher were also made to understand the environment of the classes.

Validity Design

Multiple data collection methods were used to gain a robust set of data. Variation in the environments in the control (traditional) and treatment (flipped) courses were minimized. Both the treatment and control calculus courses were taught by the same instructor and they were both morning courses. The final exam was the same between the two courses as well as almost all of the course assignments. Rich descriptions of each course were provided including classroom experience, assignments, participants, instructional strategies, supplemental material availability, and other important information about each class. Also, an interview from the instructor provided a description of instructional context. Student demographic information was described for both the control and treatment groups earlier in this chapter. According to Firestone (1993), these rich thick descriptions give readers the ability to make decisions on whether a case-to-case transfer is appropriate. Triangulation of data was used by considering multiple forms of data including quantitative final exam data, grades, ACT scores, CCR (Calculus Concept Readiness) scores (Carlson, Madison, & West, 2010), ATMI data, and multiple-choice questions involving students' intent to take Calculus II and their preference toward flipped or traditional instructional methods. Qualitative survey data included a complementary set of data that provided a holistic picture of the flipped classroom environment. The data and coding process outlined by Marshall and Rossman (2016) was followed. To take out researcher bias, the researcher was not involved in the instruction or grading process in the courses. The researcher had peer review and debriefing sessions to ensure researcher bias does not play into the results. A member check was performed on the qualitative data collected from the instructor to ensure accurate information.

To give more external validity, a comparison was made between two sections taught by the same instructor. This comparison that included standardized ACT and CCR scores as well as demographic makeup allowed the researcher to isolate the treatment as a sole contributor to the differences in student success in the two groups allowing for analytic generalizations.

Data Collection

A quasi-experimental design was used to collect quantitative data on grades and demographic information to compare the flipped calculus course to the traditional course. Qualitative data was collected through open-ended questionnaires and instructor interviews. The quantitative and qualitative data were gathered concurrently as described by Plano-Clark and Ivankova (2016). Together these data were analyzed with a mixed methods approach to provide a full-bodied complementary set of data.

Quantitative Data Collection

The quantitative approach utilized a quasi-experimental design. The design controlled for potential threats impacting the credibility of the results. Both the control group (traditional instruction) and treatment group (flipped instruction) were morning classes taught by the same instructor. This controlled for unwarranted variation by having different instructors teach the courses at different times of the day. Though students did not know at the time of course selection that the treatment course was flipped, they were informed before classes started allowing them to switch. Subsequently, students who chose to remain in the course were potentially motivated to receive this type of instruction. However, student switching was not observed to be significantly greater at the beginning of the semester for the flipped class compared to the traditional class.

Qualitative Data Collection

The qualitative student data was collected through two online surveys that can be found in appendix 1. The surveys were given around midterm and at the end of the semester. The surveys were provided to students by the professor. The professor emailed all of the students with a link to the quiz. The surveys for the flipped section included open-ended questions about the flipped classroom experience. The traditional class and flipped class both had open-ended questions that asked about their plans to take Calculus II and their preference toward flipped model instruction. The qualitative instructor data was collected using two semi-structured interviews conducted by the researcher. The instructor was also asked to keep a journal throughout the semester documenting information related to his experience with the flipped lecture course and the student interactions he observes. The researcher observed both the traditional and flipped lecture courses once a week throughout the semester to gain insight into the two courses. The researcher kept a journal throughout the semester. All course descriptions were discussed with the instructor to ensure accuracy.

Data Analysis

Quantitative Analysis

After the preliminary descriptive statistics, a non-parametric t-test was used to analyze the final exam scores since the data violated the assumptions of an independent t-test. Given that the outcome of student performance was dichotomous (pass or fail), a binary logistic regression was applied to model the outcome (e.g., Lemeshow, Sturdivant, and Hosmer, 2013). First, based on Lemeshow and his colleagues' recommendations (2013), a series of standard contingency table analyses of the outcome versus each of the categorical independent variables (i.e., gender, race, class setting, college affiliation) was examined to investigate whether each given independent variable was associated with the outcome. After that, a binary logistic regression with all covariates identified in the first step was applied to examine the effects of each of the independent variables while controlling for other variables in the model. Odds ratios were computed and used to aid in interpreting relationships between each predictor and outcome. Finally, a MANOVA was used to analyze the ATMI survey to compare the control and treatment group's attitudes towards mathematics.

Qualitative Analysis

For the qualitative data, the procedure from Marshall and Rossman (2016) was followed. As suggested by Marshall and Rossman (2016), themes from the literature were considered when developing codes for the data. Open coding was used to help find "patterns and key ideas (Marshall and Rossman, 2016, p. 222). Summaries, categories, and themes were developed by comparing the responses on the questionnaire with literature. Last, the data was interpreted. A peer debriefing was done for triangulation. The instructor kept a journal and was interviewed by the researcher throughout the semester to get a robust set of knowledge surrounding the flipped classroom experiment. This interview was analyzed using the procedures outlined by Marshall and Rossman (2016) as well.

Summary

A mixed methods research design was utilized to gain a robust data set that gave the researcher a multifaceted insight into the flipped classroom experience. The multiple data types provided complementary data that provided greater insight into the flipped classroom experience than one data source alone. The quantitative strand provided insights into the students' academic outcomes and attitudes while the qualitative strand provided rich descriptions of the student and instructor experience in the flipped classroom environment. The qualitative strand also provided insights into students' decisions to proceed to the next class in mathematics.

Chapter 4 Results

This chapter answers the following research questions related to how the flipped classroom model impacted student attitudes and outcomes in a large section Calculus I class in a sixteen-week semester.

1. What was the difference in final exam scores between students enrolled in a traditional large lecture calculus class and students enrolled in a flipped large section calculus class? (Quantitative)
2. How were pass rates of subpopulations (minority status, college of study and gender) of students different for students enrolled in a traditional large lecture calculus course and students enrolled in a flipped large section calculus course? (Quantitative)
3. How did the attitudes of students toward mathematics in the flipped lecture course compare to students in the traditional lecture course? (Quantitative)
4. How did the flipped classroom model affect students' plans to pursue Calculus II? (Integrated)
5. What were the benefits and challenges of flipped large lecture calculus courses? (Integrated)

These questions were answered through both qualitative and quantitative data analysis. The findings will be organized by research question.

Standardized Score Comparisons

To control for student type, the control and treatment groups were compared by standardized test scores to ensure the two classes contained a similar population. Of the students in the flipped class who had MATH ACT scores ($n = 128$, $M = 27.55$, $SD = 3.587$) on record compared to the students in the traditional class that reported MATH ACT scores (*n* = 145, *M* = 27.14, *SD* = 3.779), there was not a significant difference found in Math ACT scores between the two classes, *t*(271) = .916 , *p* = .361. There were also no significant difference found in the flipped (*N* = 128, *M* = 28.29, *SD* = 3.846) and traditional (*N* = 146, *M* = 28.36, *SD* = 3.993) classes' Composite ACT score, *t*(272) = -0.141, *p* = .888. Similarly, there were no significant differences found in the Calculus Concept Readiness scores between the flipped (*N* = 101, *M* = 10.80, *SD* = 3.685) and traditional (*N* = 152, *M* = 10.61, *SD* = 3.603) classes, *t*(251) = .421 , *p* = .674. The students in the two classes signed up without knowing what type of lecture format the class would be. This blind selection coupled with the similarity in standardized test scores makes the assumption that the two classes had similar populations of students valid. See Table 2 for standardized score information.

Table 2

Average incoming ACT and CCR scores for the Flipped and Traditional Courses

Exam	Flipped Course			Traditional Course		
	n	*M*	*SD*	*n*	*M*	*SD*
Calculus Concept Readiness (CCR)	101	10.80	3.685	152	10.61	3.603
ACT Composite	128	27.64	3.846	145	27.85	3.993
ACT Mathematics	128	27.55	3.587	144	27.06	3.779

Findings for Research Question 1

Research question 1 asked, "What is the difference in final exam scores between students enrolled in a traditional large lecture calculus class and students enrolled in a flipped large section calculus class?" This was a quantitative research question designed to examine whether the flipped classroom approach made a significant difference in final exam scores. The results of a non-parametric Mann-Whitney test revealed that students in the flipped class had significantly higher final exam scores than the traditional class.

The final exam was a standardized Calculus I final that was given to all Calculus I students at the University of Arkansas in the fall of 2021. The final consisted of 11 open-ended problems. Recall, students in the flipped and traditional classes entered with similar standardized test scores and held similar demographic populations. At the time of the final exam, there were $n = 122$ students enrolled in the flipped course and $n = 153$ students enrolled in the traditional course. Students who were enrolled, but did not take the final exam were recorded as zeros, while students that dropped the course before the final exam were not included in the data set. The inspection of the Q-Q Plots revealed that the final exam scores were not normally distributed and contained extreme outliers from the students who completed the course, but did not show up for the final exam and therefore made zeros on the exam. A Mann-Whitney test indicated that the final exam score was greater for the flipped section ($M = 71.45$, $Mdn = 77.73$) than for the traditional section ($M = 66.63$, $Mdn = 74.55$), $U = 7916.500$, $p = .031$.

Findings for Research Question 2

Research question 2 asked, "How are pass rates of subpopulations (minority status and gender) of students different for students enrolled in a traditional large lecture calculus course and students enrolled in a flipped large section calculus course?" This was also a quantitative research question. The inspection of the contingency table paired with a binary logistic regression indicated that the flipped classroom model was a significant contributor to pass/fail rates in the two large section Calculus I courses at the University of Arkansas.

According to the contingency table, students in the flipped class were overall more likely to pass Calculus I than the students in the traditional large section Calculus I course. Both courses were predominantly male, white, and engineering major students. So, when analyzing the data race, sex, and college were separated into binary groups of White/Minority, Female/Male, and Engineering/Other. Table 3 shows the demographic breakdown in each class section and whether they passed or failed the class. Overall, students performed better in the flipped classroom environment. The subpopulation results indicate that male students, non-engineering majors, and minority students exhibited greater disparities in pass rates than the overall flipped vs. traditional pass rates.

Table 3

Pass/Fail in the Traditional vs. Flipped Classes Separated by Sex, College, and Race

Characteristic	Flipped n = 144				Traditional n = 169			
	Pass		*Fail*		*Pass*		*Fail*	
	n	%	n	%	n	%	n	%
Sex								
Female	40	85.1	7	14.9	57	80.3	14	19.7
Male	77	79.4	20	20.6	69	70.4	29	29.6
Major								
Engineering	74	85.1	13	14.9	88	79.3	23	20.7
Other	43	75.4	14	24.6	38	65.5	20	34.5
Race								
White	84	84.0	16	16.0	100	81.3	23	18.7
Other	33	75.0	11	25.0	26	56.5	20	43.5
Total	117	81.3	27	18.8	126	74.6	43	25.4

A binary logistic regression analysis was conducted to investigate whether pass rates of students in the two large section Calculus I classes were affected by the type of lecture (flipped and traditional), sex of the student, minority status (white or minority), or the student's college (Engineering or Other). An inspection of standardized residual values revealed that there were

16 outliers which were kept in the data set (Std. residual ranging from 2.49 to 2.97). The model was statistically significant, χ^2 (4, $N = 313$) = 24.075, $p < .001$, suggesting that it could distinguish between those who would pass and fail Calculus I. As seen in Table 4 section, sex, college, and race all significantly contributed to the model.

Table 4

Logistic Regression Predicting the Likelihood of Passing Calculus I

	B	*SE*	*Wald*	*p*	*OR*	95% *CI OR*	
						LL	*UL*
Section	.59	.29	4.06	.044	1.81	1.02	3.21
Race	.95	.29	10.36	.001	2.57	1.45	4.57
Sex	.81	.32	6.42	.011	2.25	1.20	4.22
College	.84	.30	7.78	.005	2.31	1.28	4.17
Constant	-.42	.36	1.31	.252	.66		

According to the odds ratios from the model, the odds of passing Calculus I are about 1.81 times for those who were in the flipped section than those who were in the traditional section. In other words, students who were in the flipped section had increased odds of passing the class by 81%. From this model the odds of passing Calculus I are about 2.57 times Caucasian students than minority students, 2.25 for female students than male students, and 2.31 times for Engineering majors compared to non-Engineering majors. In both courses female students outperformed male students. Though all students seemed to benefit from the flipped model classroom, the categories of students who were shown from the regression model to be less likely to pass Calculus I (male, non-Engineering majors, and minority students) performed particularly well in the flipped model classroom section.

Findings for Research Question 3

Research question 3 asked, “How do the attitudes of students toward mathematics in the flipped lecture course compare to students in traditional lecture course?” This was a quantitative question based on Maria Tapia's (2004) Attitudes Toward Mathematics Inventory (ATMI). The findings indicated that there was no significant difference in the mathematical attitudes of students in the flipped and traditional sections.

There were 85 students in the traditional class and 73 students in the flipped class that completed all of the questions in the enjoyment, motivation and value subsets of the ATMI. In the self-confidence subscale, there were considerably less students that completed all of the questions. The self-confidence subscale also was not normally distributed and contained a multimodal distribution from inspecting the frequency chart. A MANOVA test was conducted on the three subscales of motivation, enjoyment, and value in mathematics. There was not a statistically significant difference in student attitudes toward mathematics in the flipped and traditional classes at the end of the semester when considering those three subscales, $F(3,154) = .362$, $p = .781$; Wilk's $\Lambda = .993$, partial $\eta^2 = .01$. A Mann-Whitney test indicated that the flipped and traditional sections were similarly distributed in their self-confidence subscale $U = 1508.00$, $p = .746$. Overall, the indication is that students' attitudes toward mathematics were not affected by the flipped classroom environment.

Findings for Research Question 4

Research question 4 asked, "How did the flipped classroom model affect students' plans to pursue Calculus II?" Two types of data were collected for this question, one quantitative and one qualitative. Students in both the flipped and traditional course were asked whether or not they planned on taking Calculus II in a questionnaire at both the beginning and end of the semester. The descriptive data from this survey is presented in Table 5. Students in both the flipped and traditional class were asked on the final survey to explain why they have or have not decided to take Calculus II. They were also asked to explain if their decision to take Calculus II changed throughout the semester and why. This data was analyzed through the qualitative process described by Marshall and Rosman (2016). The results indicate that their degree plan was the greatest contributor to whether students decided to take Calculus II or not.

Quantitative Findings

Students' intent to take Calculus II was asked on both the survey at the beginning of the semester and the survey at the end of the semester. Of the participants in the flipped class, 141 of the 144 students responded to the beginning of semester survey and 114 out of 144 responded to the end of semester survey. Of the participants in the traditional course, 160 of the 169 responded to the beginning survey while 136 out of 169 responded to the end of semester survey. Part of this attrition can be attributed to the 17 students that withdrew from the flipped course during the semester and 16 students that withdrew from the traditional section.

In the flipped section, the percent of students who responded that they intended to take Calculus II increased slightly. However, in the traditional section, the percent of students that responded that they intended to take Calculus II decreased slightly. In both courses, students had more clarity on whether or not they would take Calculus II by the end of course survey, with maybes only accounting for a small percentage of students in the final survey compared to 31.25% and 19.53% in the flipped and traditional courses on the initial survey, respectively. The number of students who did not plan on taking Calculus II increased in both the flipped and traditional as shown in Table 5. Since the flipped course initially had more "maybe" responses on the initial survey, the larger increase in "no" responses in the flipped course can be partially attributed to the larger percentage of "maybe" responses on the initial survey. In both classes, the large increase in students who did not respond can be attributed to students who dropped the course and were unavailable for the survey. See Table 5 for survey results. Also worth noting are the results from research question 2. Students in the flipped class experienced increased pass rates as compared to the traditional section. Students who do not pass Calculus I are not able to take Calculus II.

Table 5

Intent to take Calculus II

	Flipped Course (n = 144)	(%)	Traditional Course (n =169)	(%)	Total (n = 313)
Initial Survey					
Maybe	45	31.25	33	19.53	78
No	19	13.19	26	15.38	45
Yes	75	52.08	101	59.76	176
Did not respond	5	3.47	9	5.33	14
Final Survey					
Maybe	5	3.47	5	2.96	10
No	31	21.53	32	18.93	63
Yes	78	54.17	99	58.58	177
Did not respond	30	20.83	33	19.53	63

Qualitative Findings

The major theme found in the qualitative analysis was that students' decisions to take Calculus II were directly related to their future plan of study. Two other themes also developed in much smaller numbers including the enjoyment of Calculus I and students' success or lack thereof in Calculus I affecting their decisions to take Calculus II. Though these two themes existed the degree plan was overwhelming in the qualitative data.

The first open ended survey question asked, "Can you explain why you have or have not decided to take Calculus II?" Of the 144 students in the flipped section course 105 of them gave an answer involving their major or degree plan when asked why they have or have not decided to take Calculus II. One student said, “I plan on pursuing an engineering degree, and thus require the course in order to graduate.” when describing their choice to take Calculus II. On the other hand, a student who did not plan on pursuing Calculus II said, “It isn't required for my major or future interests, so I don't want to spend the money or time taking it.” Both of these decisions were made based on decisions involving degree requirements. Similar to the flipped lecture class, 121 of the 169 students in the traditional class mentioned degree requirements as a reason that they would or would not take Calculus II. An example from the traditional class was a student who answered, “It is required for my major”. The idea that students choose their mathematical coursework based on their major is consistent with literature from Kaleva et al. (2019) and Rasmussen and Ellis (2013) that suggests that students choose to pursue Calculus II based on their major and future career plans. Since 63.3% of students in the two Calculus I courses were Engineering majors, it makes sense that they would plan on taking Calculus II based on their degree plan.

Other themes that were found for why students chose to or not to take Calculus II include having to pass Calculus I before pursuing Calculus II and the enjoyment of Calculus I. A student in the flipped class said, “I decided to take it because I enjoy math.” There were two other students in the flipped section who had similar comments. In the traditional section a student said, “I enjoy math and I need classes to fill in my hours”. One other student in the traditional course had a similar comment. Though in the overall population, the success of the student Calculus I was a theme, this was not seen in the flipped section class. In the traditional class a student said, “My quality of life has taken a huge hit because of Calculus 1.” when describing why she wasn’t going to pursue Calculus II.

The second survey question asked students if their decision to take Calculus II had changed over the course of the semester. The theme that was present in the majority of students' (80 in the flipped section and 109 in the traditional section) responses, in both the flipped and traditional courses was that students did not change their mind about their decision to take Calculus II throughout the semester. According to students, the reason their decision to take Calculus II didn't change was because their decision was based on their degree plan. This is consistent with the existing literature in Rasmussen and Ellis (2013) and Kaleva (2019).

For students who did change, the only reason that was given that was common between the two classes was a negative Calculus I experience. This theme is also consistent with the literature from Rasmussen and Ellis (2013). The responses that included these themes were small in number. A student in the flipped class said, "I had a lot of trouble with the flipped classroom and it definitely affected my choice to change majors and not take Cal 2". A student from the traditional class said, "I was planning on taking Calculus 2 but Calculus 1 has convinced me to completely change majors. The money I would be making as an engineer is not worth my happiness." The flipped lecture course had four students who mentioned changing their mind and deciding to take Calculus II because they enjoyed Calculus I. This theme was not present in the traditional course. A student from the flipped course said, "Yes, I previously wasn't going to but I changed my mind because I like Math". The traditional lecture course had three students who mentioned deciding to not take Calculus II because they changed their major and it was no longer necessary. A student from the traditional class said, "I planned on taking it to continue my Engineering path however with my major change I do not need it anymore". This theme was only present in the traditional class. These two themes were only present in a small in number of responses, these responses support the idea presented by Rasmussen and Ellis

(2019) that discovered that students were less likely to switch out of their Calculus II plans when "good" and "progressive" teaching was present.

Summary of Findings for Research Question 4

Overall, students in both courses mainly described their decision to take Calculus II as a decision based on degree requirements within their major choice. Students in both classes that described a reason for changing their decision, other than changing their major, mentioned their lack of success in Calculus I or Calculus I being difficult. The majority of students in both the flipped and traditional sections are listed as engineering majors. This group of students is required to take Calculus II and according to Rasmussen and Ellis (2013), Engineering majors are less likely to switch out of taking Calculus II. Some of the students in the flipped course who decided to change their mind about Calculus II mentioned their enjoyment of Calculus I as a reason for changing their mind. However, these responses were limited. These findings are consistent with the literature of Kaleva et al. (2019) and Rasmussen and Ellis (2013) that students base their future mathematics decisions on their future career and education plans. The enjoyment of the flipped classroom is consistent with the findings of Rasmussen and Ellis (2013) that students in classes with "progressive" and "good" teaching had less students who switched from intending to take Calculus II to not intending to do so.

Findings for Research Question 5

Research question 5 asked, "what are the benefits and challenges of flipped large lecture calculus courses?" This was an integrated research question with both qualitative and quantitative components. A qualitative midterm and final survey were given to the flipped lecture class. The questions from this survey can be found in Table 6. The midterm and final survey included open ended questions designed to understand the flipped classroom experience from the students' perspective. The topics of the questions included the students experience in the flipped classroom, the learning experience, the pros and cons of the flipped classroom, and how the students' opinion of the flipped classroom changed over time. Both positive and negative codes were found in the qualitative survey data when open coding. These codes were compared with the existing literature as recommended by Marshall and Rossman (2016) to develop themes. These codes and themes can be found in Tables 7 and 8. Also, an interview with the instructor of the flipped and traditional courses was conducted at midterm and the end of the semester. Quantitative data from course grades, demographic information, and pass rates were collected.

Table 6

Qualitative Survey Questions by Topic

Topic	Midterm Survey Questions for Flipped Class	Final Survey Questions for Flipped Class
Flipped Classroom Experience	Describe your experience so far with the flipped classroom. Is there anything else that you would like to share about your experience so far in a flipped large section Calculus I course?	Describe your experience with a flipped lecture large section calculus course. Is there anything else about your experience that you would like to share?
Learning in Flipped Classroom	Do you feel like the flipped classroom environment is helping you learn Calculus I? Please explain why or why not	How has participating in a flipped lecture class impacted your learning of calculus this semester?
Pros of the flipped classroom	In your opinion what are the pros of a flipped large section Calculus I course?	
Cons of the flipped classroom	In your opinion what are the cons of a flipped large section Calculus I course?	
Opinion of flipped final vs. midterm		Are you more or less likely to take a flipped lecture course after taking this course? Please explain your reasoning. Since the midterm survey, have your opinions about a flipped large lecture calculus course changed? Please explain.

Benefits of Flipped Lecture Courses

Quantitative Findings. There is evidence in multiple forms of quantitative data that the students in the flipped section had better academic outcomes than the students in the traditional course. Final exam scores were higher in the flipped lecture (M = 71.45, Mdn = 77.73) course than the traditional lecture course (*M* = 66.63, *Mdn* = 74.55), as explained in the results under research question 1. Pass rates in the flipped lecture class (81.25%) were higher than in the traditional lecture course (74.6%) and lecture type was found to be a significant contributor to pass rates in the logistic model as seen in research question 2. Though pass rates were higher in the flipped section in all subcategories of students, the pass rates seemed to be particularly higher in the subcategories of minority, male, and non-Engineering major students. See Table 3 for details. In each class, both traditional and flipped, the same questions were used on a clicker response item in class. This was partially for attendance purposes as well as checking to see how well students understood the lesson that day. Not counting absences as zeros, the average clicker score in the traditional class was an 84% while the average clicker score in the flipped section was an 89%. Students in the flipped course seemed to show both a higher level of success and understanding of the material compared to the traditional course based on these academic outcomes.

Benefits of the Flipped Classroom from the Students' Perspective (Qualitative Findings). Several benefits of the flipped classroom environment were found when considering all of the qualitative and quantitative data collected. The quantitative grade data, the open-ended survey data, and the instructor interview were all combined to find the benefits of the flipped classroom environment. When answering questions on the open-ended questionnaire, students identified several benefits of the flipped classroom that were consistent with the existing literature on flipped classrooms. These positive themes included deeper understanding of calculus, improved grades and retention of material; video availability and flexibility; more time with the material; more problem solving, hands on, and cooperative learning; self-paced and more efficient use of class time, less stressful and overwhelming; more prepared for class; and improved experience for students with disabilities. These themes were consistent with the existing literature on the benefits of flipped classrooms and can be found in Table 7.

Table 7

Qualitative Survey – Thematic and Open Codes for Positive Student Experiences

Topic	Positive Open Codes	Positive Meaning Units and Themes
Flipped Classroom Experience	Better understanding, more prepared for class, video availability helps stay caught up, teacher implemented flipped classroom well, more problems to work, it is more work, but in a good way, improved grades, improved experience for student with disabilities	• Deeper Understanding and retention of material/Improved grades • Video availability/flexibility • More time with the material • More problem solving/hands on/ Cooperative Learning • Self-paced/efficient • Increased student responsibility • Less stressful/overwhelming • More prepared for Class • Improved experience for students with disabilities
Learning in Flipped Classroom	More time, reinforcement, more problem solving, material before, pace, ability to rewatch or rewind video, self-paced learning	
Pros of the flipped classroom	Prepared for class, more time on task, deeper problems, cooperative learning, reinforcement, rewatch videos, retain material longer, flexibility, improved grades, help stay on track, less confusion, self-teaching/pacing, helps with my learning disability	
Opinion of flipped now vs. midterm	Self-paced, more examples/practice, learn better, more hands on, efficient use of time, video accessibility, less overwhelming, easier to focus at home, more prepared for class, more time to understand, like to pause and rewind during lecture	

Deeper Understanding, Grades, and Retention of Material. Students identified deeper understanding, grades and retention of material as a benefit of the flipped classroom. When asked if the flipped class was helping you learn Calculus I, a student responded, "It is, keeps me accountable and I have noticed a boost in my learning, and retaining info." These benefits are echoed in the literature on flipped classrooms. Cheng et al. (2019) found that student learning outcomes were improved in the flipped classroom. As a student in the flipped class said, "You get better grades." Fulton (2012b) concluded that student achievement was increased in the flipped classroom model. Students were also asked to list the pros of flipped classroom learning. Many students responded with statements that show students' belief that the flipped classroom improved grades, retention, and gave them a deeper understanding of the material. When asked the pros of the class some students commented on the retention of material, one said, "Class helps me imbed what I learned in the videos in my brain." Another student said, "I feel like I'm going to remember this for longer." This is consistent with the literature from Frydenberg (2013) that noted improved understanding and retention of the material in a flipped technology course. Depth of understanding was a common theme from students in the flipped classroom. One student said, "It allows for the professor to delve into deeper and more complex topics while in lecture." Another said, "The pros of a flipped large section is that the knowledge I gain while watching the videos is that it gets further emphasized in class so what I know is strengthened." Multiple literature sources support the idea that flipped classrooms increase test scores and academic performance (Davies et al., 2013; Fulton, 2012b; Halili and Zainuddin, 2016; O'Flaherty & Phillips, 2015; Stone, 2012; Talley and Scherer, 2013). The quantitative outcomes of this study that support improved final exam scores and pass rates also support this qualitative finding. The existing literature on flipped classrooms is consistent with the theme that students benefit from improved understanding, grades and retention of material in this lecture model.

Video Availability and Flexibility. Students also identified video availability and flexibility as a benefit of the flipped classroom. This is echoed in the literature (Bergmann and Sams, 2012; Herrid and Schiller, 2013; and Scovotti, 2016). Even students who identified the flipped classroom as a negative experience mentioned the video availability as a benefit of the flipped lecture classroom. As mentioned by a student in the flipped lecture course, "it helped having videos to go back to even though it included extra work and could hurt your grade". As far as flexibility goes, students praised the fact that they could rewatch the video when needed, rewind or pause, play on a faster or slower speed, and watch on their own time. This was one of the pros that was consistently repeated among both students who preferred the flipped classroom and those who did not. One of the students in the flipped classroom commented that, "I feel that the flipped classroom is helping me learn calculus. When watching the lectures, I can rewind and pause to take moments to catch up and make sure I am understanding." This showcases how the video flexibility helps students control the way that they watch the video. In the student survey, students commented about the benefits of speeding up, slowing down, pausing and rewatching the videos. These all were listed as benefits by students in the flipped lecture course. The flexibility in video is also helpful for students who must miss class for illness or other reasons. One student commented that, "Due to sickness I've missed a multitude of lectures and having the online components has helped me at least keep somewhat up to date.". This idea of flexibility is echoed in the literature where Bergmann and Sams (2012) mentioned the benefit of students being able to pause and rewind their teacher.

Time with the Material. Another benefit that students identified in the flipped lecture model was that there is more time with the material. According to a student in the flipped classroom, "Essentially, no [expletive], if you take more of the students' time, they are going to learn the material better". In the flipped lecture model, students spend an additional 20 minutes outside of class watching the lecture video which freed up class time to work more problems. All of this adds to more time spent on calculus. This benefit of flipped classrooms is echoed in the literature from Herried and Schiller (2013). A student observed, "I think the flipped model is helping me learn the Calculus I material, because I end up spending more time than I realize on the material and getting more out of my time." This unintentional time spent on calculus gives students more time to absorb and process the material. A student noticed the repetition that was helping them absorb the material and said, "I have enjoyed the experience so far. I like being able to get introduced to the content before class and then having the ability to clearly walk through it several times in class." Another student reiterated this idea and said, "Basically a recorded class over each section we cover and I get double the coverage of each section." Also, repeated by many students was the idea that they have more time to ask questions about the material. The additional time spent on calculus was considered a benefit to many students.

Problem Solving, Hands-on (Active Learning), Time to Ask Questions, and Cooperative Learning. The next theme found in the qualitative data was that the flipped section involved more problem solving, hands-on learning (active learning), time to ask questions and cooperative learning. The literature is clear that active learning is a key to success in the study of mathematics (Boaler et al., 2011; Freeman et al., 2014; Laursen et al., 2014; Rasmussen & Kwon, 2007). A student in the flipped class noticed that, "The flipped classroom experience has worked great for me! I enjoy being able to go to class and work examples problems rather than sitting through a lecture." This class contained a much more active process than the traditional class. In my observations of both classes, students in the flipped classroom were much more active in the learning process. Repetitively, students mentioned more problem solving as a benefit of the flipped learning environment. One example of a student mentioning this benefit is, "I like the flipped classroom because it gives me a chance to work more problems, which I feel helps me retain the information better." The idea that flipped classroom models free up time for active learning is presented in the literature from Bergman and Sams (2012). A student remarked, "I like having a flipped classroom model. I wasn't too keen on watching the theory videos outside of class but I have come to like spending more time working more complicated examples in class and talking it over with my peers as it helps me understand the material much better." O'Flaherty & Phillips (2015) found that students had positive feedback on the active engagement involved in the flipped classroom. The literature from Brunsell and Horejsi (2013) found that "flipping the classroom opens up more class time for student collaboration (p. 8)" and supports the theme that students have more time to work with peers in the flipped classroom environment. Students commented that the professor was more accessible during their cooperative learning time and they were able to get more questions answered than they experienced in traditional classes. According to a student, "Even though it was a large lecture, I still had lots of time and chances to be able to ask questions and get help, and I didn't feel intimidated to do it because there is lots of time when the entire class is working through problems." There were multiple cases in the literature that mention increasing time for problem solving as a benefit of flipped classrooms (Clark, 2015; Fulton, 2012b; Gullen and Zimmerman, 2013; Lage et al., 2000; Milman, 2012; Zappe et al., 2009). This theme that students experienced greater amounts of problem solving, hands-on learning (active learning), time to ask questions and cooperative learning is consistent with the existing literature.

Self-Paced Learning. The next theme that was present in the benefits of flipped classrooms was the ability of students to self-pace in the flipped classroom as seen in this student comment, “I really like the flipped classroom because it allows me to learn at my own pace. I can pause the videos to make sure I can write everything down, and then still listen to the lecture.” Students mentioned that this style of class was more efficient, less stressful, less overwhelming, and gave them more confidence in mathematics. An example of a student’s experience is this, “The pros are that we aren’t as overwhelmed with new information and practice problems. It’s more spread out and we get more practice and time to process.” Several examples from literature Fulton (2012) and Goodwin & Miller (2013) mention self-paced learning as a benefit of the flipped classroom experience (Fulton, 2012; Goodwin & Miller, 2013; McCallum et al., 2015; Scovotti, 2016). McCallum et al. (2015) found students enjoyed being able to control their own pace in the flipped classroom environment. Teo et al. (2014) noticed that learning anxiety was reduced and efficiency was improved in the flipped classroom. Several students mentioned that the self-paced environment made the flipped environment less stressful. Thus, this theme is consistent with the literature.

More Prepared for Class and Increased Student Responsibility. The next theme that students identified as a benefit in the flipped classroom was that students were more prepared for class and were tasked with more responsibility in the flipped classroom model. This theme is consistent with the literature from Bergmann and Sams (2012) and Fulton (2012). Students identified increased student responsibility as both a benefit and a challenge in the flipped classroom. Here we will focus on the students who found this to be a benefit. Students mentioned that they had the resources and ability to learn calculus on their own. An example includes “there is a hint of self-teaching going on since the lecture is recorded, so that makes learning a lot easier.” and “I do feel like it is helping me learn Calculus I because I can try and figure it out on my own the night before class that way when I go to class, I can put all my attention into the professor and examples he gives us." Students also praised the preparation they had going into the class session. One student said, "I like it because we are able to do more practice problems in class and I feel more confident going in to class since I have already learned the material before-hand. I have enjoyed the flipped classroom model, as it allows me to introduce the topic to myself before working examples in class." The theme that students are better prepared and more capable of self-teaching is both evident in literature and in the student responses to the qualitative questionnaire.

Improved Experience for Students with Disabilities. An improved experience for students with disabilities is the last theme found in the benefits of the flipped classroom model from student responses to the questionnaire. When asked if they were more or less likely to take a flipped lecture class again, a student in the flipped lecture course noted, "More likely at least for math, because I have ADHD it's hard for me to focus on long lectures, especially with a bunch of people in the class. It's easier to focus on them at home and then do the problems in class to help me make sure I understand how to do them." According to Bergman and Sams (2012), "flipping allows for real differentiation (p. 28)". Another student in the flipped classroom commented that, "I love it, this experiment produces great results personally. I am a candidate that has dyslexia and flipped classroom really allows me to take my time and teach myself the way I learn. Thus, performing better on exams." The idea that flipped classrooms allow for true differentiation for students with disabilities is found in the literature from Brunsell & Horejsi (2013), Clark, (2015) and Davies et al. (2013). A student in the flipped classroom observed that, "It allows students to learn at their own pace, which is good because everyone learns differently." The flipped classroom allows students to learn differently and at their own pace.

Benefits of the Flipped Classroom from the Instructor's Perspective. The instructor of the two courses was interviewed by the researcher both at the midterm and end of the semester in which the data collection occurred. Several benefits of the flipped classroom from the instructor's professor were found in this interview. These themes were compared with literature and the qualitative data analysis procedure from Marshall and Rossman (2016) was followed. The professor noticed higher exam scores, more understanding from students, more engagement from students, more depth of problems, more active learning, more time spent on calculus, video availability, and the ability to reuse materials in the future. All of these benefits that the professor acknowledged are consistent with the benefits of flipped classrooms found in literature on flipped classrooms.

First, similar to the student's observations, the professor noticed that students were getting higher exam scores. This is consistent with the existing literature on academic achievement in flipped classrooms (Davies et al., 2013; Fulton, 2012b; Halili & Zainuddin, 2016; O'Flaherty & Phillips, 2015; Stone, 2012; Talley and Scherer, 2013). Next, the professor mentioned more "time on task" for the students. He noted that they were spending approximately an additional 60 minutes on calculus each week. This is again consistent with the literature on the benefits of flipped classrooms (Herried and Schiller, 2013). Next, the professor noticed that he had a better understanding of the misconceptions that students had in the flipped class compared to the traditional class. This is consistent with the findings from Fulton (2012b). The professor noticed more engagement and more active style learning in the flipped class compared to the traditional class. He noted that the traditional class didn't ask very many questions compared to the flipped class. He also noticed that he was able to discuss "richer more extended problems" in the flipped class. This is consistent with the benefits found in literature

(Bergmann and Sams, 2012; Goodwin & Miller, 2013; Halili & Zainuddin, 2016; Tally and Scherer, 2013). Last, the professor mentioned the access to the materials as a benefit of the flipped classroom. He mentioned that students could go back and watch the videos again. He also noted that he would be able to reuse the videos in future classes. The benefit of video availability is echoed in literature (Fulton, 2012b; McCallum et al., 2015; Phillips and Trainor, 2014).

Overall, the instructor of the two courses found teaching the flipped course to be a positive experience. When asked if there was anything he wanted to share about the experience he said, "So I'm glad that I finally did it and I think it was beneficial. I don't know I think I may be kind of an apostle for flipped classes for moving on right now (S. Dingman, personal communication, Dec 8, 2021)." He then said, "So I don't think I purposefully wandered into this thinking I'm going to take this by storm, but after engaging with it. I was like oh this is pretty good. This I really think that expanding the amount of time that you got and making it worthwhile, it really helped out (S. Dingman, personal communication, Dec 8, 2021)." The professor noticed several benefits of the flipped classroom including higher exam scores, more understanding from students, more engagement from students, more depth of problems, more active learning, more time spent on calculus, video availability, and the ability to reuse materials in the future. All of these benefits that the professor acknowledged are consistent with the benefits of flipped classrooms found in literature on flipped classrooms.

Challenges in the Flipped Lecture Class

When answering questions on the open-ended questionnaire, students identified several challenges of the flipped classroom that were consistent with the existing literature on flipped classrooms. These challenging themes were heavy workload on the student, couldn't ask questions in real time during the video, too much responsibility on the student, preference toward traditional and non-online learning, and video length and access time. These themes were consistent with the existing literature on the benefits of flipped classrooms and can be found in Table 8. The instructor of the course also explained some challenges of the flipped lecture model. The challenges from the instructor's perspective included a heavy amount of up-front preparation, more work on the students, and having to get use to teaching in a new way.

Table 8

Qualitative Survey – Thematic and Open Codes for Negative Student Experiences

Topic	Negative Open Codes	Negative Meaning Units and Themes
Flipped Classroom Experience	Don't like to teach myself, prefer in class lecture, don't like not being able to ask questions during lecture, hard to watch videos, workload, would like videos posted sooner	• Workload • Prefer traditional • Can't ask questions during video/Hard to watch videos • Would like access to videos sooner or videos are too long • Felt like they were having to teach themselves/ too much responsibility on the student
Learning in Flipped Classroom	Learn better with lecture, stressful, heavy workload, if confused during video lecture can't ask questions immediately, teach myself, too fast paced, don't like video	
Cons of the flipped classroom	Prefer traditional lecture/flipped lecture is different than my past experiences, too fast or slow paced (repetitive), have to teach myself and have self-motivation, if miss a video then lost in class, workload	
Opinion of flipped now vs. midterm	Hard to watch video, don't like online learning, prefer traditional, extra work/repetitive, too much responsibility on the student, can't ask questions during lecture, harder to learn	

Challenges of the Flipped Classroom from the Students' Perspective. In the qualitative data analysis process, there were several themes that came from students describing negative aspects of the flipped classroom experience. These themes included the greater workload that comes from the flipped classroom style, the difficulty in watching videos or understanding the class when the videos were not understood, student preference toward the traditional lecture model, lack of instant ability to ask questions during the video lecture portion, increased student responsibility, and dislike of the way the videos were distributed or created. The open codes that led to these themes can be seen in Table 8. These negative experiences are consistent with the challenges of flipped classrooms in literature. The instructor also mentioned some challenges from his perspective that give an insight into the behind-the-scenes challenges to running a flipped model classroom.

Workload. The first and most prominent negative theme found from the open-ended student survey was the amount of work included in a flipped lecture style classroom. Even some students who preferred the flipped classroom to the traditional style mentioned the workload as a challenge of the flipped lecture model. A student who felt positively about the flipped class overall said, "The only con I can think of is that there is more work for us outside of the classroom but I think it's worth it." Other students felt more strongly about how the workload impacted their experience. A student said, "I hate it, flipped classroom only provides more work and not enough benefit to make a difference." Another challenge with the workload could come from students that have multiple flipped lecture style courses. An example from a student in the flipped classroom said, "I do not like flipped classroom, it is a lot more work at home when I already have another class that is flipped classroom." Scovotti (2016) mentioned that a common complaint of students was that the out of class workload was too much. Therefore, the students' perceptions that the workload is a challenge is consistent with the existing literature.

Lack of Understanding from Videos. The next challenge that was consistently listed by students was that not gaining understanding from the videos meant that students were lost in class. Some students mentioned the time requirement, forgetting to watch, or simply that they didn't want to watch a video. Others mentioned that it was difficult to concentrate on a video for that long. "I do not like it as much, its hard getting myself to watch the videos." Still others mentioned that they would watch the video, but still be confused. A student from the flipped class said, "I do not always pick up the concept through watching the video so at times I can be a little lost in class." Another student said, "Many students will fail to watch the videos or just be lost watching them and go to class without a clue as to what they are doing." In any of those cases, students would then not be prepared to engage in the active learning portion of the class the following day. This challenge of flipped lecture courses was consistent with existing literature (Herried and Schiller, 2013; Milman, 2012; Phillips & Trainor, 2014; Scovotti, 2016).

Preference Toward Traditional, In-Person Learning. The next theme among the challenges listed by students in the flipped lecture course was the general preference toward a traditional lecture class or a dislike of online learning. A student commented, "It is different. I would prefer to do it regularly and not watch videos before." This is consistent with the literature from O'Flaherty & Phillips (2015) that found students were negative toward the introduction of the flipped class despite an improvement in grades. Other literature agrees that students may be resistant to flipped lecture models (Herried & Schiller, 2013; McNally et al., 2017; Phillips & Trainor, 2014; Scovotti, 2016). Similarly, some students expressed their dislike for the online components of the class. A student stated, "It can be hard to learn from a video."

Questions in Real-Time. The next challenge that was found among the student comments was that students are unable to ask questions during the video in real time. A student said, “In all honesty, it has been a struggle. I feel like I would understand the material much better if it was taught to us in class so I could ask questions as soon as they come to mind.” Another student said, “You can't ask questions during the lecture online. You have to just wait until class to ask your questions.” This is consistent with the literature from Milman (2012) and Phillips & Trainor (2014) that students don’t like that they are unable to ask questions in real-time during the lecture portion of the flipped classroom. Other students noted that this is a challenge, but recognized that it may also be a challenge of a traditional large section calculus course. A student said, “I think the cons of the large section flipped Calculus I are the same as any calculus lecture. If and when you don't understand something, it can be difficult to get the necessary help, just because of how many people are in the lecture.”

Increased Student Responsibility. One of the more widely mentioned challenges in the flipped classroom environment was that students felt like they had too much responsibility put on them in this model. Students commented that it felt like they had to “teach themselves”. This is consistent with a common complaint found in the literature from Scovotti (2016) that students felt like the instructor wasn’t teaching. When asked if the flipped classroom helped you learn Calculus I, a student responded, “Not really. I prefer my professor to take charge of my learning instead of myself.” Another student listed that the flipped classroom requires a lot of self-motivation as a con of the flipped classroom model. The challenge that a lot of responsibility is put on the students has been repeated in literature (Phillips & Trainor, 2014; Scovotti, 2016). Literature also suggests that students must be self-motivated and responsible to be successful in a flipped model classroom (Phillips & Trainor, 2014; Roehl, Reddy, & Shannon, 2013).

Video Style and Availability. The last theme found in the student comments on the challenge of the flipped classroom environment is more specific to this particular classroom. Students commented on video length and availability. This theme is consistent with Milman (2012) who found that students may feel overwhelmed by the number or length of videos in the flipped model classroom. A common comment was that students wished the videos were posted more in advance. A student said, "I think the videos could be posted a little bit more time in advance." One student even suggested posting all of the videos at the beginning of the semester. Another comment was that the videos can get too long. During the semester the professor of the class aimed for 20-minute videos. Occasionally, the videos would be longer or shorter. A student said, "The only negative aspect to it is that the videos can sometimes be so long that they feel like a whole other lecture before the lecture."

Challenges of the Flipped Lecture Class from the Instructor's Perspective

Challenges to the flipped classroom model also existed from the instructor perspective. The instructor of the course explained some of challenges of the flipped lecture model in the midterm and end-of-semester interview. The challenges from the instructor's perspective included a heavy amount of up-front preparation, more work on the students, and having to get used to teaching in a new way.

The first challenge that the instructor explained was the amount of work that it took to switch from a traditional lecture instructor to a flipped instructor. He mentioned that he essentially had to start from scratch learning a new software, creating videos and video quizzes, and creating in-class activities. Even one of the students in the class noticed that the flipped classroom was more work for the professor. The student commented that it was additional work for the professor when asked about the cons of the flipped lecture style classroom. The professor indicated that he had been teaching the class in a similar manner for the last 10 years. He learned how to use Kaltura to create video quizzes. Each quiz took time to create and upload. He also had to come up with new activities to work with the students in class including in depth problems that would extend students' learning. The professor mentioned that he believed the workload would be considerably less when teaching a flipped class for the second time. He noted that he would be able to reuse the activities and videos. He also stated that he had gotten the hang of teaching using the flipped method. Examples can be found in the literature that coincide with the idea that the adoption of the flipped classroom model can be a difficult and time-consuming task for the instructor (Long et al., 2017; Scovotti, 2016)

As mentioned in the student comments, the professor noticed that the flipped course required more work on the part of the student. He said, "From the student perspective obviously they are having to put in more work. And it is forcing them there. (S. Dingman, personal communication, Oct 13, 2021)." He went on to say though he thought it was more work, in ways that work was necessary and beneficial for students. This theme is consistent with the literature from Scovotti (2016).

The last challenge that the professor discussed was having to get use to teaching in a new way. He mentioned that initially it was difficult to decide what content to put in the video and what to do in class, but it became easier after the first few weeks. Also, the software to create the video quizzes was difficult at times. He commented that it was hard to come up with questions that didn't need mathematical symbols since they didn't work well in the video quiz software that he was using. This was consistent with Scovotti (2016) and Long et al. (2017).

Research Question 5 Summary

Overall, the benefits of the flipped classroom seemed to outweigh the challenges. Foremost, the improved academic outcomes were an exciting benefit of the flipped lecture class. It is particularly important that this improved outcome was apparent even in a large section Calculus I course. Other benefits, according to the students, were deeper understanding of calculus, improved grades and retention of material; video availability and flexibility; more time with the material; more problem solving, hands on, and cooperative learning; self-paced and more efficient use of class time, less stressful and overwhelming; more prepared for class; and improved experience for students with disabilities. According to the professor, the benefits of the flipped classroom included higher exam scores, more understanding from students, more engagement from students, more depth of problems, more active learning, more time spent on calculus, video availability, and the ability to reuse materials in the future. All of these benefits were consistent with existing literature that paints a promising picture of how flipped classrooms can increase active learning and achievement in large section Calculus I courses.

Though this study of the flipped classroom provided a very promising picture it was not without challenges. Not all students enjoyed the flipped lecture model. Students discussed the challenges of a heavy workload, lack of real-time feedback during the video lecture, too much responsibility on the student, a preference toward the traditional classroom, and their dislike of some of the attributes of the video. The challenges from the instructor's perspective included a heavy amount of up-front preparation, more work on the students, and having to get used to teaching in a new way. Some of these challenges are unique to the first year of teaching a flipped lecture course, but others will continue to be challenges that a flipped lecture instructor will deal with.

Summary

This research study showcased ways in which the flipped lecture model created opportunities for students to participate in active learning and improved outcomes despite the large lecture style of the classroom. Students in the flipped lecture course displayed higher final exam averages; higher pass rates; and particularly higher pass rates for minority students, non-engineering majors, and male students. Many students responded positively to the flipped lecture model including comments that listed deeper understanding of calculus, improved grades and retention of material; video availability and flexibility; more time with the material; more problem solving, hands on, and cooperative learning; self-paced and more efficient use of class time, less stressful and overwhelming; more prepared for class; and improved experience for students with disabilities as benefits of the flipped classroom model. The flipped classroom model also included challenges. Students noted challenges of a heavy workload, lack of real-time feedback during the video lecture, too much responsibility on the student, a preference toward the traditional classroom, and their dislike of some of the attributes of the video. The professor also noted benefits and challenges in the flipped lecture model. As a whole, this research study showcased the flipped lecture model as a great option for increasing active learning and academic outcomes for students in large lecture Calculus I courses.

Chapter 5 Discussion

Calculus I courses have long been criticized for keeping students out of the high paying and in demand STEM fields (Bressoud et al., 2015). Calculus I is taught using predominantly lecture and recitation (Roehl et al., 2013). According to Hornsby and Osman (2014) Calculus I has often been taught in large lecture sections that are counterproductive to developing critical thinking skills. Prior studies have shown that active learning and inquiry-based learning have had a positive impact on student learning, particularly for women and minority students (Boaler et al., 2011; Freeman et al., 2014; Laursen et al., 2014; Rasmussen & Kwon, 2007). However, pursuing active learning in a large section course can be very challenging. The flipped lecture model shows promise as an instructional technique that can accommodate large numbers of students effectively (Davies et al., 2013) and provide time to incorporate active learning (Bergmann & Sams, 2012; Clark, 2015; Fulton, 2012b; Gullen & Zimmerman, 2013; Milman, 2012; Zappe et al., 2009).

The mixed methods research design in this study explored multiple aspects of the viability of the flipped classroom design in a large section Calculus I course at the University of Arkansas. The rationale for the MMR design was complementarity for the purpose of triangulation, specifically to gain greater insight into the topic of flipped large section calculus courses (Bazeley & Kemp, 2012). The qualitative strand explored the benefits and challenges of the flipped model classroom from the students' perspectives and gave insight into why students may choose not to continue on to Calculus II. The qualitative strand also explored the benefits and challenges of the flipped model classroom from the perspective of the instructor. The quantitative strand explored student academic outcomes including final exams and pass rates as well as benefits of the flipped model from academic outcomes.

Though flipped lecture courses have become increasingly utilized, the research is still limited. Prior studies showed improvement in student attitudes (Scott et al., 2016) and academic outcomes (Davies et al., 2013; Fulton, 2012b; O'Flaherty & Phillips, 2015; Stone, 2012; Talley and Scherer, 2013; van Alten, 2019; Zainuddin and Halili, 2016). Also, the benefits from active learning are evident throughout literature (Aiken, 1970; Ashcraft and Krause, 2007; Boaler, 2013; Elmore et al., 1993; Evans, 2007; Hemmings and Kay, 2010; House, 1995; Ma, 1999; Ramirez et al., 2013). Though there have been studies on the effectiveness of flipped classrooms in calculus classes, there have only been three studies that have explored large section flipped calculus courses. Sun et al. (2018) found a positive correlation between students' self-efficacy and achievement in the flipped classroom. The study by Sun et al. (2018) focused on the correlation between self-efficacy and achievement in the flipped classroom, had no control group and lacked demographic information. Junic et al. (2015) conducted a study that gained insights into the instructor's perspective of flipped classrooms at Simon Fraser University. Instructors felt that the flipped classrooms were more successful, but noted the need for empirical evidence. Last, Maciejewski (2016) explored a flipped large section Calculus for Life Sciences course and found students in the flipped course outperformed students in the traditional course by 8%. This was not a Calculus I course and the data lacked demographic information. There have been no studies that explore both the quantitative and qualitative aspects of the flipped classroom model in large section Calculus I courses. Also, no studies of large section flipped calculus courses have included demographic information to consider the effects on subpopulations of students that have historically been underrepresented in the STEM fields. This study fills those gaps.

Summary of the Findings

This study illustrates that students in the flipped model classroom were able to participate in active learning and experience improved academic outcomes despite the large lecture style. Students in the flipped classroom displayed higher final exam scores on a university wide final exam than students in the traditional model. Students in the flipped model exhibited higher pass rates across all subpopulations, but particularly for minority students, non-engineering majors, and male students. Students remarked that the flipped model classroom was beneficial by giving them a deeper understanding of calculus, improved grades and retention of material; video availability and flexibility; more time with the material; more problem solving, hands on, and cooperative learning; self-paced and more efficient use of class time, less stressful and overwhelming; more prepared for class; and improved experience for students with disabilities as benefits of the flipped classroom model. Students mentioned the challenges of the flipped classroom included a heavy workload, lack of real-time feedback during the video lecture, too much responsibility on the student, a preference toward the traditional classroom, and their dislike of some of the attributes of the video. The professor also noted benefits and challenges in the flipped lecture model. As a whole, the benefits of the flipped classroom in this study outweighed the challenges. This research study showcased the flipped lecture model as a great option for increasing active learning and academic outcomes for students in large lecture Calculus I courses.

Analysis of the Findings

The quantitative findings on the academic outcomes of students in the research study both confirm and extend the knowledge in the field of mathematics education on flipped lecture classrooms. The idea that flipped lecture courses increased academic outcomes including exam scores and pass rates existed in the current literature (Davies et al., 2013; Fulton, 2012b; O'Flaherty & Phillips, 2015; Stone, 2012; Talley and Scherer, 2013; van Alten, 2019; Zainuddin and Halili, 2016). However, whether this outcome would be true in a flipped large section Calculus I course was unknown. The results of this study are encouraging. The flipped lecture model was shown to be successful at improving academic outcomes in large section Calculus I courses. Though across all subpopulations of students the pass rates were higher in the flipped lecture course, certain subpopulations of students seemed to benefit greater than others. This was true in the subpopulations of students who did not perform well overall in the two classes. Minority students benefited greatly from the flipped model in this study.

The existing literature suggests that active learning improves outcomes of all students (Rasmussen and Kwon, 2007) and particularly for minority students (Theobald et al., 2020) and students underrepresented in STEM. This study confirms that ability to participate in active learning in the flipped lecture model improved academic outcomes for minority students. Non-engineering majors also saw this increased benefit as well as male students. Though female students also experienced improved outcomes in the flipped lecture model, it was not as significant as male students. This is contrary to what was expected from the literature on active learning and the positive impact it has on women (Boaler et al., 2011; Laursen et al., 2014). However, also contrary to existing literature from Ellis et al. (2016), female students outperformed male students in both the flipped and traditional section in this study. Students across all subpopulations experienced improved outcomes in the flipped lecture course which is consistent with the literature that flipped classrooms improves academic outcomes for students (Davies et al., 2013; Fulton, 2012b; Halili nd Zainuddin, 2016; O'Flaherty & Phillips, 2015; Stone, 2012; Talley and Scherer, 2013).

The results of this study were unable to confirm the idea that students in the flipped lecture course were less likely to switch out and decide not to take Calculus II since both classes had a small number of students who switched. However, this study did offer additional details surrounding this question that were consistent with existing literature. This research study supported the literature that Engineering majors were less likely to switch from wanting to take Calculus II to deciding to opt out of Calculus II (Rasmussen and Ellis, 2013). The majority of students in both the flipped and traditional course were Engineering majors. The results also supported the literature that students base their future mathematics courses on their future career and education plans (Kaleva et al., 2019; Rasmussen & Ellis, 2013). Though small in number, the students who decided to change and take calculus mentioned enjoyment of the flipped lecture course. This is consistent with the literature from Rasmussen and Ellis (2013) that suggests that students in classes with “good” and “progressive” teaching were more likely to continue through to Calculus II.

There was not a significant difference in the students’ mathematical attitudes between the flipped and traditional classes. This may be in part to the makeup of students in these two classes. Both classes were mainly comprised of high ACT, Engineering majors. This composition of students is likely to have positive attitudes about mathematics despite what lecture style they are in (Hackett and Betz, 1983).

The results of the qualitative analysis were similar to many ideas from literature about the benefits and challenges of flipped model classrooms, and extend these ideas to specifically a large section flipped Calculus I course. All of the benefits and challenges of the flipped lecture class that students and the instructor mentioned existed as benefits in the literature. The results of this can be seen in Chapter 3. This does confirm that despite the large section nature of the flipped lecture course, the benefits that students and instructors experienced in other flipped lecture courses were consistent with the benefits in this flipped lecture course. Some of the challenges that students reported were not unique to flipped lecture courses, but exist as challenges in large lecture settings. Schullery et al. (2011) mentioned that classes held in large lecture halls had limited interaction with the professor. So, the challenge that students couldn't get immediate feedback during the video would likely still be a challenge in the traditional lecture course. The challenges of workload and increased student responsibility are consistent with literature as seen in Chapter 3. However, the professor noted that this was a positive from his perspective, and that students often don't put in the necessary work to be successful in Calculus I. The flipped model encourages this student responsibility. The challenge related to the video availability and length are both challenges that can be addressed by professors of flipped classrooms once they get used to teaching in a flipped style classroom.

Overall, the results of this research study confirm that the flipped lecture model allowed time for active learning and improve academic outcomes for students, and that the benefits of the flipped classroom outweigh the challenges. One student from the flipped class commented,

> When I first heard about the flipped classroom, I was not thrilled at all. I was already worried about coming into calculus with no calculus experience at all and I was afraid that this was going to make me do even worse in this course. I think that it has actually helped me more than I thought it would. I really enjoy getting to work the problems in class because getting to work with the actual content instead of learning the definitions and writing for most of the class helps me understand the steps and the process to solving the problems.

This adds a layer of important information for academic leaders at the university level when finding ways to increase success in large section courses.

Limitations

This study cannot be statistically generalized to a broader population, because the sample population was not a random sample representative of all students. This was controlled for by students signing up for courses without knowing the lecture style. The quasi-experimental quantitative data from this study can be generalized analytically. According to Firestone (1993), analytic generalization applies evidence to support (but not prove) a theory. According to Firestone (1993), "when one generalizes to a theory, one uses the theory to make predictions and then confirms those predictions (p. 17)".

The information gained from this study could be used to inform of the potential success of similar classes conducted at other large public universities. However, students in this study were a homogeneous set of students. They were predominantly white, male, and engineering major students with high ACT scores. This makes generalizations difficult for schools with a different population of students in their Calculus I courses. Through descriptions of the course design, participants, instruction, and methodology, it was possible to generalize utilizing what Firestone (1993) called a case-to-case translation (also known as a case-to-case transfer). According to Polit and Beck (2010), in a case-to-case transfer, the researcher can "provide detailed descriptions that allow readers to make inferences about extrapolating the findings to other settings. (p. 1453)". The comparison of the flipped and traditional courses taught by the same instructor allow for potential knowledge that could transfer to other large section Calculus I courses and possibly other large section mathematics courses. The qualitative data assisted in understanding the reasoning behind the success or failure of the students in the flipped course.

There were limitations to the data analysis on research question 3 involving the ATMI (Tapia, 2004). Many students did not complete all of the questions for the ATMI and were therefore left out of the data set. This was possibly due to survey fatigue. Also, one of the questions on the self-confidence subscale was missing in the online survey. Another limitation of this analysis was the homogeneous nature of the students in the flipped and traditional courses that were studied. Many of the students in the two courses were engineering majors with high ACT mathematics scores. These two factors likely contributed greatly to students' attitudes towards mathematics (Hackett and Betz, 1983).

Another limitation in this study was the relatively small sample size. In this data set several of the subpopulations, including students who "switched", minority populations, etc. were small and therefore the data analysis was limited. Because the students self-selected the courses and voluntarily participated in the survey, there may have been selection bias and differing participant characteristics introducing unwarranted variation in into the analysis. Though students did not know at the time of signing up which course was flipped, and which one was traditional, they were informed at the beginning of the semester which could have allowed them to switch courses. However, large numbers of students switching lecture types was not observed in the flipped lecture course.

Suggestions for Future Research

Further research should be conducted with larger, more diverse, populations of students. A study that includes a subpopulation of students that were identified as "at-risk" would build upon the results of this study. This could include first-generation, low ACT, and other risk factors for not being successful in Calculus I. A similar model of flipped instruction could also be explored with other large section courses in mathematics like College Algebra. Another suggestion for future research would be to extend this study to a much larger population of students across multiple universities. This could provide a richer data set to consider the effect of the flipped lecture course on student's decision to take Calculus II. Finally, a longitudinal study that tracked the success of students who participated in flipped or active learning Calculus I courses through their later STEM courses could determine if academic results such as improved test scores would have additional positive residual effects. Students mentioned that they felt like they were understanding and retaining the material in Calculus I better in the flipped course. It would be interesting to see if these findings could be verified quantitatively. Ultimately, the results from these research studies would inform researchers if the effects from Calculus I were making an impact on retaining students in STEM.

Another body of research that needs to be pursued is the best practice for running a large lecture flipped classroom. According to Bull, Ferster, and Kjellstron (2012), "Because the concept is relatively new and still evolving, little research is available to guide best practices (p. 11)." In the qualitative data, students discussed other flipped classes that they had experienced in the past. Many of them were negative in comparison to the flipped calculus class that they were enrolled in at the University of Arkansas. Some described classes that sounded more like online classes while others described reading a textbook before class as a flipped model classroom. There is a wide range of class styles within the flipped lecture model, particularly post COVID-19 pandemic. The professor of the flipped model class in this research study was new at flipping classes, but had a great experience. There was a lot of upfront learning on his part. It would be helpful to future professors to have insights into how to run a successful large section calculus course to be able to incorporate active learning, interactive videos, and other helpful tools.

A topic of interest that came up in the qualitative portion of this study was the student suggestion that video availability may have an impact on student learning as well. An experimental design approach to determine if having video lesson availability in a traditional course impacts student learning would add to the positive impacts found in this study. It's possible that a video component would improve student learning in different types of instructional models.

Implications

The results of this study are impactful for the field of mathematics education at the collegiate level. Though educators have long been aware that active learning is a preferred method of instruction, it has not been easy in the large lecture environment. Using a flipped classroom model in large lecture mathematics courses can bring active learning into the collegiate classroom. Higher pass rates in Calculus I can have a direct impact on a university's STEM education programs since Calculus I functions as a gatekeeper for other STEM courses (Bressoud et al., 2015). Flipped classrooms may also provide a pathway for underrepresented populations to be successful in mathematics courses. Another way that the flipped model classroom can be impactful is the ability of universities to utilize the flipped classroom as a means of growth and professional development for professors. Videos of an outstanding instructor can be utilized to train other instructors or used in the place of graduate assistant instructors. Another way the results of this study can be impactful is to reopen the discussion of improving undergraduate mathematics instruction. Though this class used a flipped model to increase active learning, there are multiple ways that universities can increase the amount of time students spend actively engaged in their lessons. These findings will be particularly important for leaders in university mathematics departments and possibly other STEM departments.

Conclusions

It is important for universities to seek out ways to help students succeed in high paying, high demand STEM fields. If Calculus I can change from a gatekeeper to a pipeline more students would have access to these jobs. Since large lecture courses have been shown to be a hinderance (Hornsby & Osman, 2014) and active learning has been shown to improve success and progress students to higher level mathematics (Boaler and Staples, 2008), it makes sense that university leaders would look to improve large lecture courses by incorporating active learning. Since this can be challenging because of time constraints, the flipped lecture model is a great addition to large lecture mathematics classes. This research study found that the flipped classroom improved final exam scores and pass rates particularly for minority students. Many students had a positive view of the flipped classroom identifying several benefits including deeper understanding of calculus, improved grades and retention of material; video availability and flexibility; more time with the material; more problem solving, hands on, and cooperative learning; self-paced and more efficient use of class time, less stressful and overwhelming; more prepared for class; and improved experience for students with disabilities as benefits of the flipped classroom model. Students also identified challenges in the flipped lecture model including a heavy workload, preference toward a traditional model, lack of real-time feedback during the video lecture, too much responsibility on the student, and their dislike of some of the attributes of the video. The professor indicated that the flipped model classroom required a lot of upfront work, but it was worthwhile to see the outcome.

The flipped lecture model in the large lecture calculus course has potential to improve the outcomes for students and potentially increase participation in STEM. Though further research is required, the outcome of this study gives a promising picture for students in flipped model large section mathematics courses. It also gives university leaders ideas in ways to improve the large lecture experience for students and instructors.

References

ACT Technical Manual. (2020). Retrieved from ACT Research Website: https://www.act.org/content/dam/act/unsecured/documents/ACT_Technical_Manual.pdf

Adams, C., & Dove, A. (2018). Calculus students flipped out: The impact of flipped learning on calculus students' achievement and perceptions of learning. *Primus: Problems, Resources, and Issues in Mathematics Undergraduate Studies, 28*(6), 600-615.

Aiken, L. R. (1970). Attitudes toward mathematics. *Review of Educational Research, 40*(4), 551-596.

Allen, D., & Tanner, K. (2017). Infusing active learning into the large-enrollment biology class: Seven strategies, from the simple to complex. *Cell Biology Education*.

Alpay, E., & Gulati, S. (2010). Student-led podcasting for engineering education. *European Journal of Engineering Education, 35*(4), 415-427.

Ashcraft, M., & Krause, J. (2007). Working memory, math performance, and math anxiety. *Psychonomic Bulletin & Review, 14*(2), 243-248.

Balaban, R. A., Gilleskie, D. B., & Tran, U. (2016). A quantitative evaluation of the flipped classroom on a large lecture principles of economics course. *Journal of Economic Education, 47*(4), 269-287.

Barr, R. B., & Tagg, J. (1995). From teaching to learning: A new paradigm for undergraduate education. *Change, 27*(6), 12-25.

Bazeley, P., & Kemp, L. (2012). Mosaics, triangles, and DNA: metaphors for integrated analysis in mixed methods research. *Journal of Mixed Methods Research, 6*(1), 55-72.

Beek, J., Ven, S., Kroesbergen, E., & Leseman, P. (2017). Self-concept mediates the relation between achievement and emotions in mathematics. *British Journal of Educational Psychology, 87*(3), 478-492.

Beesley, A., Apthorp, H., & (Eds.). (2010). *Classroom instruction that works, second edition: Research report.* Denver, CO: McRel.

Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class everyday.* Washington D.C.: International Society for Technology in Education.

Bergmann, J., & Sams, A. (2015). *Flipped learning for math instruction.* Eugene, OR: International Society for Technology in Education.

Berrett, D. (2012). How 'flipping' the classroom can improve traditional lecture. *The Chronicle of Higher Education*.

Boaler, J. (2008). Promoting "relational equity" and high mathematics achievement through an innovative mixed abiltiy approach. *British Educational Research Journal, 34*(2), 167-194.

Boaler, J. (2013). Ability and mathematics: The mindset revolution that is reshaping education. *Forum*, 143-152.

Boaler, J., & Staples, M. (2008). Creating mathematical features through an equitable teaching approach: The case of Railside School. *Teachers College Record, 110*(3), 608-645.

Boaler, J., Altendorff, L., & Kent, G. (2011, August). Mathematics and science inequalities in the United Kingdom: when elitism, sexism, and culture collide. *Oxford Review of Education, 37*(4), 457-484.

Bolliger, D., Supanakorn, S., & Boggs, C. (2010). Impact of podcasting on student motivation in the online learning environment. *Computers and Education, 55*(2), 714-722.

Bonwell, C., & Eison, J. (1991). *Active learning: Creating excitement in the classroom.* Washington, DC: Association for the Study of Higher Education.

Boster, F. J., Meyer, G. S., Roberto, A. J., Inge, C., & Strom, R. (2006). Some effects of video streaming on educational achievement. *Communication Education, 55*(1), 46-62.

Bressoud, D., & Rasmussen, C. (2015). Seven Characteristics of Successful Calculus Programs. *Notices of the AMS, 62*(2), 144-146.

Bressoud, D., Mesa, V., & Rasmussen, C. (Eds.). (2015). Insights and Recommendations from the MAA National Study of College Calculus. *MAA Press*.

Bressoud, David; Rasmussen, Chris;. (2015). Preface. In D. Bressoud, C. Rasmussen, & V. Mesa, *MAA National Study of College Calculus* (pp. v - vii). Mathematical Association of America.

Brunsell, E., & Horejsi, M. (2011). "Flipping" your classroom. *The Science Teacher, 78*(2), 10.

Brunsell, E., & Horejsi, M. (2013). Flipping your classroom in one "take". *The Science Teacher, 80*(3), 8.

Bull, G., Ferster, B., & Kjellstrom, W. (2012). Inventing the flipped classroom. *Learning & Leading with Technology, 40*(1), 10-11.

Carlson, M., Madison, B., & West, R. (2010). *The Calculus Concept Readiness (CCR) Instrument: Assessing Student Readiness for Calculus.*

Chen, X. (2013). STEM Attrition: College students' paths into and out of STEM fields. Statistical Analysis Report. *National Center for Education Statistics*.

Cheng, L., Ritzhaupt, A., & Antonenko, P. (2019). Effects fo the flipped classroom instructional strategy on students' learning outcomes: a meta-analysis. *Edcuational Technology Research and Development*, 793-824.

Clark, K. (2015). The effects of the flipped model of instruction on student engagemnt and performance in the secondary mathematics classroom. *Journals of Educators Online, 12*(1), 91-115.

Creswell, J., & Poth, C. (2018). *Qualitative Inquiry and Research Design: Choosing Among Five Approaches* (4th ed.). United States of America: SAGE Publications, Inc.

Davies, R., Dean, D., & Ball, N. (2013). Flipping the classroom and instructional technology integration in a college-level information systems spreadsheet course. *Educational Technology Research and Development*, 563-580.

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

Ehrenberg, R. (2010). Analyzing the factors that influence persistence rates in STEM fields, majors: Introduction to the symposium. *Economics of Education Review, 29*(6), 888-891.

Ellis, J., Fosdick, B., & Rasmussen, C. (2016). Women 1.5 times more likely to leave STEM pipeline after calculus compared to men; Lack of mathematical confidence a potential culprit. *PLOS ONE, 11*(7).

Ellis, J., Kelton, M., & Rasmussen, C. (2014). Student perceptions of pedagogy and associated persistence in calculus. *ZDM Mathematics Education*, 661-673.

Elmore, P., Lewis, E., & Bay, M. (1993). Statistics achievement: A function of attitudes and related experience. *Paper presented at the annual meeting of the American Educational Research Association.* Atlanta, GA.

Evans, B. (2007). Student attitudes, conceptions, and achievement in introductory undergraduate college statistics. *The Mathematics Educator, 17*(2), 24-30.

Fernandez, V., Simo, P., & Sallan, J. (2009). Podcasting: A new technological tool to facilitate good practice in higher education. *Computers and Education, 53*(2), 385-392.

Firestone, W. A. (1993). Alternative arguments for generalizing from data as applied to qualitative research. *Educational Researcher*, 16-23.

Freeman, S., Eddy, S., McDonough, M., Smith, M., Okoroafor, N., Jordt, H., & Wenderoth, M. (2014). Active learning increases student performance in science, engineering, and mathematics. *Procedings of the National Academy of Sciences*, (pp. 8410-8415).

Frydenberg, M. (2013). Flipping Excel. *Information Systems Education Journal, 11*(1), 63-73.

Fulton, K. (2012a). Upside down and inside out: Flip your classroom to improve student learning. *Learning & Leading with Technology*, 12-17.

Fulton, K. (2012b). 10 Reasons to flip. *Kappan Magazine*, 20-24.

Gamst, G., Meyers, L., & Guarino, A. J. (2008). *Analysis of variance designs: A conceptual and computational approach with SPSS and SAS.* Cambridge, UK: Cambridge University Press.

Goodwin, B., & Miller, K. (2013). Research says evidence on flipped classrooms is still coming in. *Technology-Rich Learning, 70*(6), 78-80.

Goolsby, C. B. (1988). Factors affecting mathematics achievement in high-risk college students. *Research and Teaching Development, 4*(2), 18-27.

Greene, J., Caracelli, V., & Graham, W. (1989). Toward a conceptual framework for mixed method evaluation designs. *Educational Evaluation and Policy Analysis, 11*(3), 255-274.

Gross, D., Pietri, E. S., Anderson, G., Moyano-Camihort, K., & Graham, M. J. (2015). Increased preclass preparation underlies student outcome improvement in the flipped classroom. *CBE Life Science Education, 14*(4).

Gullen, K., & Zimmerman, H. (2013). Saving time with technology. *Educational Leadership, 70*(6), 63-66.

Hackett, G., & Betz, N. (1983). Mathematics self-efficacy expectations, mathematics performance, and the consideration of math-related majors. *Journal of Vocational Behavior, 23*(3), 329-345.

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement.* New York, New York: Routledge.

He, W., Holton, A., & Farkas, G. (2018). Impact of partially flipped instruction on immediate and subsequent course performance in a large undergraduate chemistry course. *Computers and Education*, 120-131.

He, Y., Swenson, S., & Lents, N. (2012). Online video tutorials increase learning of difficult concepts in an undergraduate analytical chemisty course. *Journal of Chemical Education, 89*(9), 1128–1132.

Hembree, R. (1990). The nature, effects and relief of mathematics anxiety. *Journal for Research in Mathematics Education*, 33-46.

Hemmings, B., & Kay, R. (2010). Prior achievement, effort, and mathematics attitude as predictors of current achievement. *The Austrailian Educational Researcher, 37*(2), 41-58.

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

Hill, J., & Nelson, A. (2011). New technology, new pedagogy? Employing video podcasts in learning nad teaching about exotic ecosystems. *Environmental Education Research, 17*(3), 393-408.

Holbrook, J., & Dupont, C. (2011). Making decision to provide enhanced poscasts to post-secondary science students. *Journal of Science Education and Technology, 20*(3), 233-245.

Hong, D., Choi, K., & Runnalls, C. (2017). Integral student's experiences: Measuring instructional quality and instructors' challenges in Calculus I lessons. *International Journal of Research in Education and Science, 3*(2), 424-427.

Hornsby, D. J., & Osman, R. (2014). Massification in higher education: large classes and student learning. *Higher Education, 67*(6), 711-719.

House, J. D. (1995). Student motivation, previous instructional experience, and prior achievement as predictors of performance in college mathematics. *International Journal of Instructional Media, 22*(2), 157-167.

Jungic, V., Kaur, H., Mulholland, J., & Xin, C. (2015). On flipping the classroom in large first year calculus courses. *Journal of Mathematical Education in Science and Technology*, 508-520.

Kaleva, S., Pursianinen, J., Hakola, M., Rusanen, J., & Muukkonen, H. (2019). Students' reasons for STEM choices and the relationship of mathematics choice to university admission. *International Journal of STEM Education*.

Kay, R. (2012). Exploring the use of video podcasts in education: A comprehensive review of the literature. *Computers in Human Behavior, 28*(3), 820-831.

Kivunja, C., & Kuyini, A. (2017). Understanding and applying research paradigms in educational contexts. *International Journal of Higher Education, 6*(5), 26-41. Retrieved from https://doi.org/10.5430/ijhe.v6n5p26

Kogan, M., & Laursen, S. (2014). Assessing long-term effects of inquiry-based learning: A case study from college mathematics. *Innovative Higher Education*, 183-199.

Krueger, G. B., & Storlie, C. H. (2015). Evaluation of a flipped classroom format for an introductory-level marketing class. *Journal of Higher Education Theory and Practice, 15*(1), 19-36.

Lage, M., Platt, G., & Treglia, M. (2000). Inverting the classroom: A gateway to creating an inclusive learning environment. *The Journal of Economic Education, 31*(1), 30-43.

Larsen, S., Glover, E., & Melhuish, K. (2015). Beyond good teaching: The benefits and challenges of implementing ambitious teaching. In D. Broussoud, V. Mesa, & C. Rasmussen (Eds.), *Insights and Recommendations from the MAA National Study of College Calculus* (pp. 93-105). MAA Press.

Laursen, S. L., Hassi, M.-L., Kogan, M., & Weston, T. J. (2014). Benefits for women and men of inquiry based learning in college mathematics: A multi-institution study. *Journal for Research in Mathematics Education, 45*(4), 406-418.

Lemeshow, S., Sturdivant, R., & Hosmer Jr., D. W. (2013). *Applied Logistic Regression* (3rd ed.). Hoboken, NJ: John Wiley & Sons Inc.

Lenning, O. (1975). Predictive validity of the ACT tests at selective colleges. Iowa City, IA: ACT Publications.

Linn, M., & Hyde, J. (1989). Gender, mathematics, and science. *Educational Researcher, 18*(8), 17-27.

Long, T., Cummins, J., & Waugh, M. (2017). Use of the flipped classroom instructional model in higher education: instructors' perspectives. *Journal of Computing in Higher Education, 29*(2), 179-200.

Ma, X. (1999). A meta-analysis of the relationship between anxiety toward mathematics and achievement in mathematics. *Journal for Research in Mathematics Education, 30*(5), 520-540.

Maciejewski, W. (2016). Flipping the calculus classroom: an evaluative study. *Teaching Mathematics and its Applications: An International Journal of the IMA, 35*(4), 187-201.

Marshall, C., & Rossman, G. (2016). *Designing Qualitative Research* (6th ed.). Thousand Oaks: SAGE.

McCallum, S., Schultz, J., Sellke, K., & Spartz, J. (2015). An examination of the flipped classroom approach on college student academic involvement. *International Journal of Teaching and Learning in Higher Education, 27*(1), 42-55.

McGivney-Burelle, J., & Xue, F. (2013). Flipping calculus. *Primus: Problems, Resources, and Issues in Mathematics Undergraduate Studies, 23*(5), 477-486.

McNally, B., Chipperfield, J., Dorsett, P., Del Fabbro, L., Frommolt, V., Goetz, S., . . . Rung, A. (2017). Flipped classroom experiences: student preferences and flip strategy in a higher education context. *Higher Education, 73*(2), 281-298.

Milman, N. (2012). The flipped classroom strategy: What is it and how can it be used? *Distance Learning, 11*(4), 9-11.

Moreno, D., Palacios, A., Barreras, A., & Pascual, V. (2020). An assessment of the impact of teachers' digital competence on the quality of videos developed for the flipped math classroom. *Mathematics, 8*(2), 148.

Nouri, J. (2016). The flipped classroom: for active, effective, and increased learning- especially for low achievers. *International Journal of Educational Technology in Higher Education*, 1-10.

O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higer education: A scoping review. *The Internet and Higher Education*, 85-95.

Onwuegbuzie, A. J., & Collins, K. M. (2007). A typology of mixed methods sampling designs in social science research. *The Qualitative Report, 12*(2), 281-316.

Onwuegbuzie, A. J., & Leech, N. L. (2007). Sampling designs in qualitative research: Making the sampling process more public. *The Qualitative Report, 12*(2), 238-254.

Phillips, C., & Trainor, J. (2014). Millennial students and the flipped classroom. *Journal of Business and Educational Leadership, 5*(1), 102-112.

Pierce, R., & Fox, J. (2012). Vodcasts and active-learning exercises in a "flipped classroom" model of a renal pharmacotherapy module. *American Journal of Pharmaceutical Education, 76*(10).

Plano Clark, V. L., & Ivankova, N. V. (2016). *Mixed methods research: A guide to the field.* SAGE Publications, Inc.

Polit, D. F., & Beck, C. T. (2010). Generalization in quantitative and qualitative research: myths and strategies. *International Journal of Nursing Studies*, 1451-1458.

Prensky, M. (2001). Digital natives, digital immigrants. *On the Horizon, 9*(5), 1-6.

Prince, M. (2013). Does active learning work? A review of the research. *Journal of Engineering Education*, 223-231.

Ramirez, G., Gunderson, E., Beilock, S., & Levine, S. C. (2013). Math anxiety, working memory, and math achievement in early elementary school. *Journal of Congition and Development, 14*(2), 187-202.

Rasmussen, C., & Ellis, J. (2013). Students who switch out of Calculus and the reasons they leave. In M. Martinez, & A. Castro Superfine (Ed.), *Procedings of the 35th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 457-464). Chicago, IL: University of Chicago.

Rasmussen, C., & Kwon, O. (2007). An inquiry-oriented approach to undergraduate mathematics. *The Journal of Mathematical Behavior, 26*(3), 189-194.

Rasmussen, C., Ellis, J., Zazkis, D., & Bressoud, D. (2014, July 15). Features of successful calculus programs at five doctoral degree granting institutions. *Paper presented at the Joint Meeting of the International Group for the Psychology of Mathematics Education (PME) (38th) and the North American Chapter of the Psychology of Mathematics Education*. Vancouver, Canada.

Renfro, A. (2014). Assessing the effects of a flipped classroom approach on student achievement, mathematical thinking, attitudes and teacher perceptions in an undergraduate calculus class using a participatory action research approach. *Dissertation*.

Reyneke, F., & Fletcher, L. (2014). The impact of an inverted traditional teaching model on first level statistics students. *Paper presented at the Ninth International Conference on Teaching Statistics*. Flagstaff, AZ.

Rice, P., Beeson, P., & Blackmore-Wright, J. (2019). Evaluating the impact of a quiz question within an educational video. *TechTrends*, 522-532.

Roehl, A., Reddy, A., & Shannon, G. (2013). The flipped classroom: An opportunity to engage millennial students through active learning strategies. *Jounal of Family & Consumer Science, 105*(2), 44-49.

Rossi, R. (n.d.). Improving student engagement in organic chemistry using the inverted classroom model. *Paper presented at the 2014 American Chemical Society Division of Chemical Education on Computers in Chemical Education Online Conference*.

Sahin, A., Cavlazoglu, B., & Zeytuncu, Y. (2015). Flipping a college calculus course: A case study. *Journal of Educational Technology & Society, 18*(3), 142-152.

Schullery, N., Reck, R., & Schullery, S. (2011). Toward solving the high enrollment, low engagement dilemma: A case study in introductory business. *International Journal of Business, Humanities, and Technology, 1*(2), 1-9.

Scott, C., Green, L. E., & Etheridge, D. L. (2016). A comparison between flipped and lecture-based instruction in the calculus classroom. *Journal of Applied Research in Higher Education, 8*(2), 252-264.

Scovotti, C. (2016). Experiences with flipping the marketing capstone course. *Marketing Education Review, 26*(1), 51-56.

Seymour, E., & Hewitt, N. (1997). *Talking about leaving: Why undergraduates leave the sciences.* Boulder, CO: Westview Press.

Seymour, E., & Hewitt, N. (1997). *Talking about leaving: Why undergraduates leave the sciences.* Boulder, CO: Westview Press.

Shymanski, J., & Matthews, C. (1974). A comparative labrotory study of the effects of two teaching patterns on certain aspects of behavior of students in fifth grade science. *Journal of Research in Science Teaching*, 157-168.

Slavin, R. (1980). Cooperative learning. *Review of Educational Research, 50*(2), 315-342.

Steen, L. (1988). Calculus for a new century: A pump, not a filter. *Papers presented at a colloquium October 28-29, 1987.* Washingon, DC: Mathematical Association of America.

Stone, B. (2012). Flip your classroom to increase active learning and student engagement. *Paper presented at the 28th Annual Conference on Distance Teaching and Learning*, (pp. 1-5). Madison, WI.

Strayer, J. (2012). How learning in an inverted classroom influences cooperation, innovation and task orientation. *Learning Environments Research*, 171-193.

Sun, Z. (2015). The role of self-regulation on students' learning in an undergraduate flipped math class. *The Ohio State University ProQuest Dissertations Publishing*.

Sun, Z., Xie, K., & Anderman, L. (2018). The role of self-regulated learning in students' success in flipped undergraduate math courses. *The Internet and Higher Education*, 41-53.

Talley, C. P., & Scherer, S. (2013). Increasing academic performance with student-recorded lectures and practice testing in a "flipped" STEM course. *The Journal of Negro Education, 82*(3), 339-347.

Tapia, M. (1996, November 6-8). The attitudes toward mathematics instrument. *Paper presented at the Annual Meeting of the Mid-South Educational Research Association*. Tuscaloosa, AL.

Tapia, M. (2004). An instrument to measure mathematics attitudes. *Academic Exchange Quarterly, 8*(2).

Tapia, M., & Marsh, G. (2003, November 5-7). Unisex math: Narrowing the gender gap. *Paper presented at the Annual Meeting of the Mid-South Educational Research Association*. Biloxi, MS, United States of America.

Tapia, M., & Marsh, G. (2004). An instrument to measure mathematics attitudes. *Academic Exchange Quarterly*, 16-21.

Teo, C., & Wan, M. (2014). How flip teaching supports undergraduate chemistry laboratory learning. *Chemistry Education and Research Practice, 15*(4), 550-567.

Theobald, E., Hill, M., Tran, E., Agrawal, S., Arroyo, E., Behling, S., . . . Freeman, S. (2020, March 24). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *PNAS, 117*(12), 6476-6483.

Thorndike-Christ, T. (1991). *Attitudes toward mathematics: Relationships to mathematics achievement, gender, mathematics course-taking plans, and career interests.* Bellingham, WA: Western Washington University.

Traphagan, T., Kucsera, J. V., & Kishi, K. (2010). Impact of class lecture webcasting on attandance and learning. *Educational Technology Research and Development, 58*(1), 19-37.

Turra, H., Carrasco, V., Gonzalez, C., Sandoval, V., & Yanez, S. (2019). Flipped classroom experiences and their impact on engineering students' attitudes towards university-level mathematics. *Higher Education Pedagogies*, 136-155.

van Alten, D., Phielix, C., Janssen, J., & Kester, L. (2019). Effects of flipping the classroom on learning outcomes and satisfaction: a meta-analysis. *Educational Research Review*, 1-18.

Vaughan, M. (2014). Flipping the learning: An investigation into the use of the flipped classroom model in an introductory teaching course. *Education Research and Perspectives, 41*(1), 25-41.

Zainuddin, Z., & Halili, S. H. (2016). Flipped classroom research and trends from different fields of study. *International Review of Research in Open and Distributed Learning, 17*(3).

Zappe, S., Leicht, R., Messner, J., Litzinger, T., & Lee, H. W. (2009). Flipping the classroom to explore active learning in a large undergraduate course. *American Society for Engineering Education Annual Converence & Exhibition.*

Ziegelmeier, L. B., & Topaz, C. M. (2015). Flipped calculus: A study of student performance and perceptions. *PRIMUS*, 847-860.

Appendix I

Instructor Interview Questions

Midterm Interview Questions

1. How was your traditional class structured?
2. How was your flipped lecture class structured?
3. What differences did you notice in the two courses for the students?
4. What differences did you notice in the two courses for the instructor?
5. Did you notice a difference in student engagement/attitude in the flipped and traditional courses?
6. Outside of class, did you notice a difference in amount of time spent with students in the traditional vs flipped course?
7. What do you see as pros of the flipped classroom model? Cons?
8. What do you see as pros of the traditional classroom model? Cons?
9. If you were to flip a class in the future is there anything that you would change?
10. Will you flip any classes in the future?
11. Is there anything else that you would like to add about your experience with the flipped classroom model?

Final Interview Questions

1. Now that the semester is complete, can you discuss the pros of the flipped class?
2. What about the cons of the flipped model?
3. Is there anything that you would change about the structure of the flipped class if you did it in the future?
4. Is there anything else you'd like to add about your experience teaching a flipped class?
5. Is there anything else you would like to add?

Student Survey Questions

ATMI Questionaire

Directions: This inventory from Maria Tapia (1996), consists of statements about your attitude toward mathematics. There are no correct or incorrect responses. Read each item carefully. Please think about how you feel about each item. Enter the letter that most closely corresponds to how each statement best describes your feelings. Please answer every question.

Please use the response codes: 1- strongly disagree
2- Disagree
3- Neutral
4 – Agree

5- Strongly Agree

1. Mathematics is a very worthwhile and necessary subject
2. I want to develop my mathematical skills
3. I get a great deal of satisfaction out of solving a mathematics problem
4. Mathematics helps develop the mind and teaches a person to think
5. Mathematics is important in everyday life
6. Mathematics is one of the most important subjects for people to study
7. College math courses would be very helpful no matter what I decide to study
8. I can think of many ways that I use math outside of school
9. Mathematics is one of my most dreaded subjects
10. My mind goes blank and I am unable to think clearly when working with mathematics
11. Studying mathematics makes me feel nervous
12. Mathematics makes me feel uncomfortable
13. I am always under a terrible strain in a math class*
14. When I hear the word mathematics, I have a feeling of dislike
15. It makes me nervous to even think about having to do a mathematics problem
16. Mathematics does not scare me at all
17. I have a lot of self-confidence when it comes to mathematics
18. I am able to solve mathematics problems without too much difficulty
19. I expect to do fairly well in any math class I take
20. I am always confused in my mathematics class
21. I feel a sense of insecurity when attempting mathematics
22. I learn mathematics easily
23. I am confident that I could learn advanced mathematics
24. I have usually enjoyed studying mathematics in school
25. Mathematics is dull and boring
26. I like to solve new problems in mathematics
27. I would prefer to do an assignment in math than to write an essay
28. I would like to avoid using mathematics in college
29. I really like mathematics
30. I am happier in a math class than in any other class
31. Mathematics is a very interesting subject
32. I am willing to take more than the required amount of mathematics
33. I plan to take as much mathematics as I can during my education
34. The challenge of math appeals to me
35. I think studying advanced mathematics is useful
36. I believe studying math helps me with problem solving in other areas
37. I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in math
38. I am comfortable answering questions in math class
39. A strong math background could help me in my professional life
40. I believe I am good at solving math problems.

*Question was inadvertently left off of the student survey

Student Survey 1 Both Classes (First Week of Class)

1. Name
2. Student ID Number
3. Do you plan on taking Calculus II after this course? (Yes, no, maybe)
4. Would you purposefully enroll in a flipped lecture course when given an equal option of a traditional lecture course? (Yes, no, no preference)
5. ATMI

Student Survey 2 Flipped Lecture Class (Midterm)

1. Describe your experience so far with the flipped classroom.
2. Do you feel like the flipped classroom environment is helping you learn Calculus I? Please explain why.
3. In your opinion, what are the pros and cons of a flipped Calculus I course?
4. Is there anything else you would like to share about your experience so far in a flipped large section Calculus I course?
5. If you have previously had a Calculus I course, how would you compare this course to your previous experience?
6. Describe how you typically watch the Calculus I videos? (multiple choice)

Student Survey 3 Flipped Lecture Class (Last Regular Week of Class)

1. Name
2. Student ID Number
3. Do you plan on taking Calculus II after this course? (Yes, no, maybe)
4. Would you purposefully enroll in a flipped lecture course when given an equal option of a traditional lecture course? (Yes, no, no preference)
5. Do you plan on taking Calculus II after this course? If this answer changed from the beginning of the semester, explain your reasoning.
6. Please explain why you have or have not chosen to take Calculus II after this course.
7. Are you more or less likely to enroll in a future flipped course after having participated in this flipped class? Explain your reasoning.
8. Describe your experience with the flipped classroom.
9. Do you feel like the flipped classroom environment helped you learn Calculus I? Please explain why.
10. In your opinion, what are the pros and cons of a flipped course?
11. Is there anything else you would like to share about your experience in a flipped large section Calculus I course?
12. ATMI

Student Survey 2 Traditional Lecture Class (Last Regular Week of Class)

1. Name
2. Student ID Number
3. Do you plan on taking Calculus II after this course? (Yes, no, maybe)
4. Would you purposefully enroll in a flipped lecture course when given an equal option of a traditional lecture course? (Yes, no, no preference)
5. Do you plan on taking Calculus II after this course? If this answer changed from the beginning of the semester, explain your reasoning.
6. Please explain why you have or have not chosen to take Calculus II after this course.
7. Based on your calculus course experience this semester and what you might have heard from students taking the flipped lecture class, are you more or less likely to take a flipped lecture course in the future. Please explain your reasoning.? Explain your reasoning.
8. ATMI

Appendix II

IRB Protocol

UNIVERSITY OF ARKANSAS

To:	Kimberly L. King
From:	Douglas J Adams, Chair IRB Expedited Review
Date:	06/22/2021
Action:	**Exemption Granted**
Action Date:	06/22/2021
Protocol #:	2104328560
Study Title:	Can flipped classrooms improve large lecture calculus courses?

The above-referenced protocol has been determined to be exempt.

If you wish to make any modifications in the approved protocol that may affect the level of risk to your participants, you must seek approval prior to implementing those changes. All modifications must provide sufficient detail to assess the impact of the change.

If you have any questions or need any assistance from the IRB, please contact the IRB Coordinator at 109 MLKG Building, 5-2208, or irb@uark.edu.

cc: Laura B Kent, Key Personnel