Examining the Influence of a Flipped Mathematics Course on Preservice Elementary Teachers' Mathematics Anxiety and Achievement

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Abstract
While the foundations of future mathematics skills are established within the elementary classroom, many elementary school teachers and preservice teachers have significant anxiety and low confidence in their ability to teach mathematics. This has the potential to impact their effectiveness in teaching and negatively influence their students' ability to learn mathematics. This study examined whether utilizing the flipped classroom approach to teach a required mathematics course for elementary preservice teachers influenced their level of mathematics anxiety and achievement in the course. Using the MARS-R anxiety rating scale, pre/post course survey results showed that both the flipped and standard classes had significantly decreased mathematics anxiety scores. In contrast, the flipped class showed significantly higher overall achievement on overall course grades. Additionally, correlational analyses of the post-course math anxiety survey and the overall course grades showed a significant negative relationship for the traditional class, while no correlational relationship was found for the flipped classroom. This suggests that while the course may have provided a positive experience that helped decrease students' anxiety, additional opportunities, due to removal of the lecture, may have allowed for the flipped students to learn more over the course of the semester.

1. Introduction

1a. Mathematics Anxiety

Elementary teachers play a significant role in students' potential achievement and attitudes about learning, especially in mathematics. While positive learning experiences in mathematics can lead students to become interested in STEM related fields, negative learning experiences can lead students to avoid mathematics and even form mathematics anxiety [4]. Mathematics anxiety has been well established as involving tensions and fears of solving mathematical problems both in class and common life situations [27].

The primary concern with mathematics anxiety is that it has the potential to influence students' long-term perceptions and achievement in mathematics classes. Middle and high school students with high mathematics anxiety have been found to have lower perceptions of their mathematics skills, lower expectations of performance in mathematics, and a lower overall perceived value of mathematics [20]. This anxiety often can persist and influence performance as well. For example, one study found that university students with high mathematics anxiety performed significantly lower on all levels of mathematical problem solving, even basic forms of elementary operations [17]. The negative effects of mathematics anxiety on achievement have been found in students as early as elementary school [26]. A meta-analysis found this relationship to have a negative correlation of -0.31, which suggests that as one's mathematics anxiety increases, his/her achievement in mathematics is likely to decrease [11]. This presents a challenge to our country's goals to improve STEM education and increase STEM related jobs as poor performance in mathematics will continue to drive high anxiety about mathematics. Mathematics anxious students are more likely to avoid such fields and future education opportunities in these areas.

With mathematics anxiety possibly forming as early as elementary school, it is important that elementary school teachers provide positive learning environments that can help mitigate this problem. However, studies have found that students majoring in elementary education have more anxiety of mathematics than students in any other major [10, 18]. A study of 167 senior elementary preservice teachers found that 60% of the students had moderate or high mathematics anxiety [4]. Correlational analysis of the open-ended questions also suggested that participants who described having a worst/troublesome mathematics experience during their primary or secondary mathematics classes had significantly higher mathematics anxiety than university students who stated that they had no bad experiences. The author summarized, "The results of this study further suggest that the worst experience and most troublesome mathematics classroom experience are major causes of mathematics anxiety" (p. 324). Within the descriptions of the bad experiences, two of the most common issues were the hostility of the teacher and the teacher's inadequacy to teach mathematics. This suggests that the mathematics teacher's disposition and instructional practices have the potential to create poor experiences for students that in turn can lead to increased mathematics anxiety.

The possibility that a significant percentage of preservice elementary teachers have mathematics anxiety creates concern for the teaching and learning of mathematics that will occur in their future classrooms. This could imply that the foundations of mathematics may often be taught by teachers who may not like and/or may not feel comfortable teaching mathematics. In addition, mathematics anxiety has the potential to influence a teacher's overall mathematics teaching efficacy, thus impacting what and how mathematical concepts are taught. For example, one study found that elementary preservice teachers' mathematics teaching efficacy was inversely related to their mathematics anxiety such that as one's mathematics anxiety increased, mathematics teaching efficacy decreased [31]. This suggests that preservice teachers with high mathematics anxiety do not feel they are adequately prepared to effectively teach mathematics to elementary students.
Preservice elementary teachers leaving their university programs with high mathematics anxiety and low teaching efficacy have the potential to begin the cycle of creating mathematically anxious students within their own classes. In particular, elementary school female students in classes with highly mathematics-anxious female teachers significantly decrease in mathematics achievement over the course of a year [3]. In addition, female students in these classes tend to agree with the stereotypical belief that boys are better at mathematics and girls are better at reading. As female teachers comprise at least 90% of the elementary education workforce [6], the long-term effects created in these classrooms may become an issue in bringing more female students into advanced mathematics and STEM-related fields in college. For example, a study found that in comparison to male students, female students scored significantly lower on the mathematics portion of the SAT, were significantly more anxious about mathematics, and were less confident in their mathematics skills [7].

1b. Improving Mathematics Anxiety

While high mathematics anxiety and low mathematics teaching efficacy can cause serious long-term challenges in education, various studies have examined how these issues can be addressed and mitigated. For example, preservice teachers' participation in an elementary mathematics methods course can significantly decrease their mathematics anxiety [32]. Participation can also help improve students' mathematics teaching efficacy [13].

Research has also suggested that approaches for improving student success in mathematics classes can alleviate their mathematics anxiety and avoidance of mathematical situations. For example, one study found that by altering mathematics problems to improve a student's success rate through a computer-adaptive program, elementary students' mathematics anxiety decreased and their overall

mathematics performance increased [14]. The researchers proposed "that practicing mathematics frequently at one's own ability level improves mathematics performance, and that the experience of success stimulates this practice" (p. 196). This suggests that if students can be provided more positive learning opportunities in which they experience success in mathematics, there is potential to decrease mathematics anxiety and increase achievement.

The use of reform-oriented practices in mathematics classes has also provided positive learning opportunities that lead to improved achievement and confidence in mathematics. These practices emphasize the use of collaborative, student-centered, cognitively demanding activities. Strong significant positive correlations have been found between professors who used learner-centered practices as measured by the *Reform Teaching Observation Protocol* (*RTOP*) in teaching undergraduate mathematics classes and student achievement [19]. At Massachusetts Institute of Technology, a classroom program focused on creating an interactive, inquiry-based, learner-centered instructional approach showed significant increases in student achievement and attendance in comparison to their corresponding traditional large lecture classes [8]. Moreover, teachers who participate in a greater number of undergraduate courses in which the professors used learner-centered practices were more likely to use such practices in their teaching of K-12 mathematics [16]. These studies suggest that providing actively engaging, student-centered learning opportunities can positively influence student achievement in mathematics, which may in turn decrease mathematics anxiety.

1c. The Flipped Classroom Approach

An instructional method which has not yet been examined with respect to influences on mathematics anxiety is the flipped classroom approach. The flipped classroom provides a medium between the two dichotomies of teaching mathematics: lecture-based instruction and student-centered instruction. There are commonly four "pillars" associated with the flipped classroom approach: a flexible environment, a shift in the culture of learning, a focus on intentional content, and shift in the role of educators [34] (Table 1). In a flipped classroom, students are expected to watch some form of lecture videos as part of their homework. This serves two purposes. First, watching the video and taking notes primes the students for learning and applying the concepts during the following class, which has been shown to improve recall of information [5]. Additionally, this allows for the following class time to incorporate a more flexible learning environment that can then be used in a variety of ways to enhance student learning [34]. For example, students can complete practice problems that may have served as homework in a traditional class. With no lecture necessary, teachers may also have time to complete more comprehensive student-centered, discovery-based, collaborative activities. This shifts the learning culture from a passive environment to an active learning environment, which research has suggested improves student learning and achievement [8]. In addition, participation to such courses can positively influence preservice teachers to incorporate such methods when they enter the K-12 classroom [16].

Another benefit of the flipped approach is that students are able to work in small groups and receive help directly from their peers. Work in small groups has been found to improve students' ability to focus on tasks, their beliefs in the importance of the task, and their overall engagement in the class [24]. When peer instruction is not enough, the teacher also has the ability to provide one-on-one instruction and tutor the student during class time, which is a method widely held to improve student learning and achievement. Dr. Lodge McCammon, founder of the FIZZ Flipped Classroom Training Program, suggests that "the true power of the flipped classroom, if done right, is that it makes teachers more efficient, more reflective, and it gives them an unprecedented ability to strengthen relationships with students, parents, and the community" [9].

Having access to lectures outside of the class provides additional unique advantages that may not have been available previously. For example, individual watching of the videos can help remove common classroom distractors [29]. Students can access lectures when they are most needed and convenient for the student [33]. Moreover, these videos can be paused, rewound, and reviewed however many times a student feels is needed, which is not an option with in-class lectures.

Table 1: Difference in the Traditional Instruction and the Flipped Classroom Approach

Traditional Instruction	**Flipped Classroom Approach**
• Class primarily consists of teacher-directed lecture • Students passively listen and write notes • Most student practice occurs outside of class and individually • Most group work, if any, occurs outside the classroom • Teacher learns of student deficiencies primarily after homework is handed in or after assessments	• Lectures are video recorded and watched outside of class • Class primarily consists of student-centered instructional practices • Students actively complete practice during class • Students often work in partners or small groups during class • Teachers learn of student deficiencies by reviewing work as students complete it during each class, thus review and remediation can happen as needed and with the students who need it

The growing research on the flipped classroom approach has typically had positive results. For example, the availability of videos of the lectures in mathematics college courses can significantly increase course grades [33]. At the K-12 level, Clintondale High School in Detroit, Michigan significantly decreased their failure rate in mathematics and increased overall attendance after teachers shifted their classroom instruction to the flipped method [28]. Recent studies on student perceptions of the flipped classroom have also been primarily positive. For example, a recent study found that in a survey of high school students in flipped mathematics class, 84% preferred the flipped model over traditional instruction, 83% would recommend taking a flipped class to a friend, and 85% felt the flipped classroom provided greater opportunities to communicate with their peers [15]. Another study found similar results with a flipped community college statistics course in that 90% preferred taking flipped mathematics classes, 100% would recommend other students to take a flipped class, 95% felt the opportunity to collaborate during class was helpful, and 100% found the in-class activities beneficial to their learning [1].

The flipped classroom method appears to provide multiple advantages for students who struggle with mathematics and/or have high mathematics anxiety. This method may provide more time for practice and collaboration in class, as well as provide more chances to seek help from the teacher. When combined, these additional opportunities have the potential to provide a more positive learning experience for students. However, it is unknown whether such experiences may have any influence on students' mathematics anxiety, achievement, and the relationship between the two. The purpose of this study was to examine whether such factors were influenced by the flipped classroom approach for students in a required mathematics course for elementary education preservice teachers. Specifically, this study examined the following questions:

1. Does participation in a flipped mathematics classroom influence mathematics anxiety?
2. Does participation in a flipped mathematics classroom influence mathematics achievement?

2. Method

This study was conducted at a mid-sized public university in the Mid-Atlantic Region. Prior to applying to the elementary education program at the university, students are required to pass the *Praxis I* (https://www.ets.org/praxis). The *Praxis I* is a national standardized test for those entering the teaching profession. It measures skills in reading, writing, and mathematics. At the time of this study, the mathematics portion consisted of 46 multiple choice questions that emphasized four content categories: number and quantity; algebra; geometry and measurement; and data analysis and probability.

In addition to passing the *Praxis I*, students are required to successfully complete three mathematics courses. The first course, *Mathematics Content for Teachers I*, emphasizes fundamental concepts in number and operations, algebra, and data analysis. The second course, *Mathematics Content for Teachers II*, emphasizes fundamental concepts in geometry, measurement, probability, and statistics. The third course, *Mathematics for Social Analysis*, utilizes these mathematical principles to examine local, national, and global social issues with lessons that can be transferred into an elementary or middle school classroom.

2a. Description of Course Design

This study focused on the first required mathematics course, *Mathematics Content for Teachers I.* Two of the classes taught by one of the researchers were used for this study. This allowed for the teaching style, expectations, and assignments to stay consistent between the two classes. The two classes were taught twice a week for 75 minutes each day. They occurred back-to-back in the same room, thus the classes occurred at similar times in the day. The room configuration was kept the same for both classes. Students sat at hexagonal tables with 6 chairs. Both classes used the textbook, *Mathematics for Elementary Teachers with Activity Manual 3rd Edition* [2]. This book was chosen because it incorporates both the fundamental principles of elementary and middle school mathematics while also providing examples of instructional methods and accompanying manipulatives that can be used for teaching elementary mathematics concepts. Additional class demographics can be seen in Table 2.

Table 2: Demographics of each Section of *Mathematics Content for Teachers I*

Section	**Number of Students that Completed the Class**	**Class Status**		**Gender**	
Standard	27	Freshman	13	Male	8
		Sophomore	9	Female	19
		Junior	1		
		Senior	4		
Flipped	35	Freshman	13	Male	6
		Sophomore	16	Female	29
		Junior	3		
		Senior	3		

To examine the influence of the flipped classroom approach on mathematics anxiety and achievement, the two classes were taught using different instructional methods. The first class was taught using standard methods of instruction for the course, and will be referred to as the SC. A typical class began with the instructor checking homework while students completed warm up questions that were on the class website. The instructor then reviewed any questions about the homework and warm ups. Once all questions were asked, the instructor led an in-class lecture for approximately 20 minutes and utilized *PowerPoint*. All *PowerPoint* presentations were uploaded to

the class website for students to review. After the reviews and lecture, approximately 40 minutes would remain. For this final portion of time, the instructor would focus on making class more student-centered and engaging. The instructor would use *SMART Notebook* to project practice exercises and activities. These activities often included the use of manipulatives, and students were expected to collaborate with the other students at their table. Homework would continue to have students extend their knowledge from the lecture and in-class activities.

The second class was taught using the flipped classroom approach, and will be referred to as the FC. Prior to class, the FC watched and took notes on instructor-created section-specific lecture videos as part of their graded homework. The videos were the same *PowerPoint* files that were used in the SC class. However, since time was not needed for students to copy notes or to ask questions, a typical video would only last 5-10 minutes. All videos were uploaded to YouTube and were cataloged in playlists for each chapter and section of the textbook: https://www.youtube.com/user/DrDoveMath/playlists?shelf_id=4&view=50&sort=dd. All lecture videos and playlists for other courses can be found at https://www.youtube.com/user/DrDoveMath/. Like the SC, a typical class would begin with the instructor checking homework, including their lecture video notes, while students completed warm up questions that were on the class website. The instructor then reviewed any questions about the homework and warm ups, as well as general questions from the lecture video. With no lecture, the flipped class would cover all of the same practice problems and activities as the SC, plus an additional 20 minutes of in-class practice or extension activities. These activities often included the use of manipulatives, and students were expected to collaborate with the other students at their table. Like the SC, *SMART Notebook* was used to project most practice exercises and activities. The same homework practice would be assigned to the FC. In addition, students were required to watch and take notes on the video lecture for the upcoming material. An example lesson can be reviewed at https://sites.google.com/site/flipmathclass/example-lessons.

2b. Data Collection and Analysis for Mathematics Anxiety

To determine the influence of the instruction on mathematics anxiety, the Mathematics Anxiety Rating Scale Revised (MARS-R) was utilized [12]. While there are multiple forms of mathematics anxiety surveys, the MARS-R was chosen for its rigorous analysis and abbreviated length. The original MARS included 98 Likert scale questions in which participants would rate a statement about a mathematical situation from low anxiety (1) to high anxiety (5) [27]. MARS has since been revised with most variations consisting of around 25 questions. Utilizing factor analyses of various revised MARS surveys, MARS-R was constructed using only 12 questions [12]. The abbreviated length of MARS-R was considered a positive component in alleviating anxiety students may have for taking a survey about mathematics anxiety.

The MARS-R was transferred into a Google Form [12]. An identical form of the MARS-R survey was created for both pre-course and post-course survey. All surveys required students to include their university ID number so that the pre-course MARS-R could be paired with each student's corresponding post-course MARS-R to measure any changes in mathematics anxiety over the course of the semester. The post-course survey also asked students three open ended questions relating to how they felt the course influenced their mathematics anxiety, their ability to teach mathematics, and suggestions on how to improve the course to help others with mathematics anxiety.

The pre-course survey was administered during the second class of the semester. Students were provided a pre-created URL that took them directly to the online survey. Students were given the final 20 minutes of class to complete the survey either on their personal computing device or at the

computer lab near the classroom. Students were allowed to leave once the survey was completed or if they wished to not take the survey. The post-course survey was administered the class prior to last day of the semester. Students were given the same instructions, provided 20 minutes to complete the survey, and allowed to leave upon completion of the survey or if they wished not to take the survey.

Once the semester had ended, the pre-course and post-course surveys were exported to *SPSS* for data analysis. Each student's survey was summed to give him/her a composite score on the pre-survey and post-survey. Scores could range from 12 (answering "1-Not anxious at all" for every question) to 60 (answering "5-Highly Anxious" for every question). Each student's composite scores were then paired. Any composite score that did not have a pair was removed from the sample. Out of a possible 27 paired survey sets, the SC had 15 complete sets (56%). Out of a possible 35 paired survey sets, the FC had 28 complete sets (80%). Paired-samples t-tests were first conducted to examine whether there were changes in mathematics anxiety levels within each class. Afterward an independent-samples t-test was conducted to examine whether there was a significant difference in the mean difference scores of the FC and the SC.

2c. Data Collection and Analysis for Achievement

Unlike data collection that occurred for mathematics anxiety, no pre-course measure of mathematics achievement was utilized. Careful thought was given to the advantages and disadvantages of not conducting a pre-course achievement test. Since it was possible that students might enter the course highly anxious, it was determined that a pre-course measure containing potentially unfamiliar material might add to this anxiety and thus skew analysis on that component of the study.

Instead multiple measures were taken to allow for comparison of final course grade. First, on the pre-course MARS-R survey, students were provided a multiple select question "What mathematics courses did you take in high school?" This question was asked to determine whether the students in each class had comparable backgrounds. Survey responses suggested that the two classes did have comparable mathematical backgrounds (Table 3). While the grade distribution within these high school classes is unknown, all students had taken Algebra I, Algebra II, and Geometry, which were the primary foundation courses for the current course.

Table 3: Classes taken in High School

Section	Number of Students that completed the survey	Algebra I	Algebra II	Geometry	Pre-Calculus	Statistics	Calculus
Standard	24 of 27	24	24	24	14	5	3
Flipped	35 of 38	35	35	35	19	6	4

The overall course grade since it was cumulative and thus encompassed mathematics concepts ranging over all that the students were expected to have learned throughout the entire semester. More importantly, course requirements, material coverage, and graded assignments were almost identical between the two classes. Both classes completed the mathematical content on the same days and were assigned the same homework practice problems and warm up problems. The only difference in homework was that the SC was assigned recommended sections from the book to read and the FC was required to watch and take notes on the lecture videos. Homework accounted for 7.5% of their course grade.

Students also completed an online warm-up at the beginning of every class. This warm-up included 3 to 5 questions related to the material covered in the previous class. The warm-up questions were identical within each class. Warm-up problems accounted for 7.5% of their course grade.

During the semester, students were given two identical projects. The first project focused on students gaining experience with the *Praxis I* test. Students are required to pass this national mathematics test in order to be accepted into the Elementary Education program. Students completed two online *Praxis I* practice exams. In addition, they required to turn in their work for each problem and provide a brief explanation on how to solve the problem. The second project required students to complete two of the state's released End of Course Mathematics Tests for elementary and middle school students, show all work, and provide a brief explanation on how to solve the problem. They were also required to determine the Bloom's Taxonomy level for each question and explain why it was at that level. The purpose of this project was to expose students to the tests their students would be taking once they began teaching and to better understand the level of mathematical rigor these tests would likely pose to their elementary students. The projects accounted for 30% of their course grade.

Throughout the semester, both classes completed the same 5 tests and final exam. Three tests were online to have students become comfortable with online testing like they would be doing on the *Praxis I*. Online tests were 20 multiple choice questions. The other two tests were in class and consisted of 10 multiple choice and five free response questions. The final exam consisted of nine department required multiple choice questions, 11 instructor-created multiple choice questions, and 5 free response questions (Figure 1). Tests were graded at the same time to keep consistency in grading between the two classes. Multiple choice questions were graded as correct or incorrect, and free response questions were graded using a rubric to limit instructor bias. The tests accounted for 40% of their course grade, while the final exam accounted for 15% of their course grade.

To analyze differences in achievement, an independent-samples t-test was conducted to compare the mean overall course grades between the FC and the SC. Additionally, correlational analyses were conducted to examine whether the literature-based negative correlation between course grades and mathematics anxiety was maintained for each section. To complete this analysis, Pearson correlations were conducted for each section between students' post-course MARS-R scores and their final course grades.

Figure 1: Sample Test and Final Exam Questions

1) A cookie recipe calls for 4 cups of flour for every $\frac{2}{3}$ cup of sugar. You want to keep this ratio and make a batch of cookies that requires 9 cups of flour. How much sugar will you need to use?

2) There are 24 students in class. Every student shakes hands with every other student in the class. How many handshakes will there be?

3) I watch a candle burn and collect the data below. How many minutes will it take for my candle to burn completely out?

Minutes	Candle Height (inches)
10	21.5
20	19
30	16.5
40	14

4) My baby pool holds 28 gallons, 2 quarts, and 7 ounces of water. The pool currently has 13 gallons, 3 quarts, and 18 ounces of water. How much more water should be added to fill the pool?

3. Results

3a. Mathematics Anxiety

As the number of paired samples for the survey was under 30 pairs for each class, the Kolmogorov-Smirnov Test was run on each data set. This verified normality existed within the data, thus parametric tests were conducted. Additionally, reliability analysis was conducted on the pre-course MARS-R survey responses and the post-course MARS-R survey responses. Cronbach's alpha was 0.936 the entire pre-course survey and 0.946 on the entire post-course survey. Additionally, when each item was analyzed using "Cronbach's Alpha if Item Deleted," every individual item maintained a value between 0.927 and 0.946 on both surveys, thus suggesting strong reliability within each survey.

A paired-samples t-test was conducted to compare whether there was a significant difference within each section's pre/post-course MARS-R survey scores (Table 4). The survey scores in both classes had a significant decrease from the pre-survey to post-survey. This suggests that completion of the *Mathematics Content for Teachers I course*, whether taught using standard methods or the flipped classroom approach, led to a significant decrease in mathematics anxiety.

Table 4: Pre-Course and Post-Course Mean Scores on the MARS-R Survey

	Mean Survey Scores			
	Pre-Course	Post-Course	*t*	*df*
Standard Class (SC)	33.4 (15.3)	23.5 (12.4)	3.53*	14
Flipped Class (FC)	34.7 (11.0)	28.1 (11.6)	3.61*	27

*Note: * p<0.01. Standard Deviations appear in parenthesis*

Since both classes showed a significant decrease in anxiety over the course of the semester, an independent-samples t-test was conducted to compare the change in mathematics anxiety between the FC and the SC. To complete this analysis, the difference score between the pre/post-course MARS-R surveys for each student was utilized. This score was found by subtracting the pre-course survey score from the post-course survey score, thus a negative score represented a decrease in mathematics anxiety. No significant difference in mathematics anxiety was found between the FC

in-class instructional practices and use of the lecture videos provided a unique and positive learning environment not experienced in previous mathematics classes. For example, a FC student suggested that the class format kept her feeling positive about mathematics and engaged in the class, stating "[The instructor] made the class fun and interesting, and it helped me to stay interested and excited to learn." Another FC student suggested that she appreciated the inverted format, stating, "I loved the setup of the class! Doing the notes for homework and a lot of practice problems in class was super helpful!" In addition, 18% of FC students specifically suggested that they found the lecture videos and notes requirement beneficial. As one student commented, "The thing that was the most helpful to me was the flipped classroom design. I was able to take my notes outside of class and then work with specific problems in class. I became more familiar with the material and I was able to understand it better. Don't change that [professor]!" This suggests that while the professor's general strategies, regardless of format, may have helped students overcome general anxiety of mathematics, students were better able to recognize and appreciate the use of student-centered learning strategies that they will be expected to incorporate when they begin teaching elementary mathematics.

3b. Mathematics Achievement

Although no pre-course achievement test was administered to limit early anxiety in the course, student backgrounds in mathematics were comparable between the two classes. To examine differences in achievement, an independent samples t-test was conducted on the final course grade between the FC and the SC. Results found that the FC had a significantly higher average grade than the SC (Table 5). This suggests that participation in the flipped class may have had a positive influence on improving overall mathematics achievement for the content of this course by almost a full letter grade.

Table 5: Final Course Grade Comparisons

	Class			
	Standard Class	Flipped Class	*t*	*df*
Final Course Grade	80.8 (14.3)	88.5 (5.3)	2.93**	60

*Note: **p<0.01. Standard Deviations appear in parenthesis*

3c. Relationships between Mathematics Anxiety and Mathematics Achievement

To examine whether a negative correlation between mathematics anxiety and achievement was present within each section, correlation analyses were conducted to examine the relationship between the overall course grade and MARS-R post-course score. Comparable to the literature, results of the correlational analysis for the SC students' post-course anxiety survey and overall course grade found a significant inverse relationship between the two areas, $r(15) = -0.43$, $p < 0.05$. This suggests that within the SC, as students' level of mathematics anxiety increased, their overall course grade significantly decreased. However, analysis of the FC students' post-course anxiety survey and overall course grades found no significant relationship between the two areas, $r(27) = -0.20$, $p = 0.149$. This suggests that in the FC section, students' level of mathematics anxiety was not significantly related to their overall course grade.

4. Discussion

The purpose of this study was to examine whether different instructional practices used in a required mathematics course for elementary education students had any influence on students' levels of mathematics anxiety, perceptions of mathematics, and mathematics achievement. Results suggested that students in both classes had a significant decrease in mathematics anxiety after completing the course. These results suggest that similar to the positive influence mathematics

methods courses have on mathematics anxiety and teaching efficacy [13, 32], mathematics content courses for education students can potentially have a similar influence on elementary education students' beliefs about mathematics and help them decrease their levels of mathematics anxiety.

One factor that may have influenced there being no statistically significant differences between changes in mathematics anxiety was the teacher and class environment. Beyond differences in survey return rates, it is also possible that while the SC was not completely representative of "traditional" lecture-based mathematics classes. On a typical day, students received about 20 minutes of lecture with the rest of time spent on in-class activities. Additionally, students' positive responses about the influence of the instructor support previous research that strong teaching can improve students' motivation and engagement in class [25, 30, 35]. It is quite possible that while highly mathematics anxious teachers can negatively influence mathematics anxiety, strong teachers who provide autonomy in supportive learning environments may be able to help mitigate students' mathematics anxiety. More research is needed to examine this specific concept.

While flipped classroom students' mathematics anxiety decreased as much as students in the traditional classroom, open-ended responses suggested that there may have been other positive factors that were not necessarily measured within the scope of this study. Opportunities for engagement, collaboration, and discussion were not measured, but were stated only in FC students' responses and suggest that the students recognized the difference in this learning opportunity as well. As one FC student reflected, "I think that if [the instructor] has all of his courses the way he set up this course, with online notes, then it will be beneficial and [students will have] less anxiety towards math."

These qualitative differences suggested by the students may have been what led to the FC students earning a significantly higher overall course grade. This supports previous research that suggests that increased use of learner-centered practices during class can improve achievement in mathematics [16]. While these learner-centered practices were used when time permitted after the lecture in the SC, the use of lecture videos outside of class allowed for the FC to incorporate on average 20 minutes more each class for individual and small group interactions and provided the instructor with a better idea of what concepts students were struggling with during class. Over the course of the semester, this additional 20 minutes per class summed to about 4 weeks of class that were spent in a student-centered, active learning environment that the SC class had to use to cover lecture material. This would not have been possible without a flipped classroom approach. By removing the lectures from the class, the instructor is provided more time to incorporate student-centered teaching practices that NCTM has been suggesting for over 25 years [21, 22, 23]. The opportunity to utilize such research-based practices was greatly enhanced primarily because lectures were not part of the allotted time for class.

The lack of the negative relationship between mathematics anxiety and mathematics achievement for the FC while significantly present for the SC at the end of the semester also provides a surprising result that supports a difference between the two methods of instruction [11]. Such a finding could suggest that some characteristics of learning in a flipped classroom can potentially help highly anxious students succeed at the same level as students with low mathematics anxiety. More research is needed to specifically examine differences in mathematics achievement between traditional and flipped classes, the influence of mathematics anxiety on achievement within each instructional practice, and why such a relationship may occur within the flipped class.

The results of this study support the growing positive research related to the flipped classroom approach. For example, access to online lecture videos can have a significant positive effect on

final grades [33]. Additionally, student survey responses showed preference to lecture videos over in-class lectures and a positive response to the opportunities to collaborate in student-centered in-class activities [1]. The results of these studies continue to suggest that the flipped classroom approach can provide a positive overall learning experience, not because the lectures occur outside of class but because opportunities for student-centered active learning opportunities are more able to occur within class.

There are several limitations to this study. First, no standardized metric was administered to measure pre/post-course achievement. As stated earlier, this was intentionally not done out of concern that a pre-course achievement test might have increased student's anxiety levels and therefore artificially inflated their pre-course MARS-R composite scores. The researchers worked to limit this issue by providing identical graded activities to both sections, thus making the final grades comparable. Additionally, the mathematical background was comparable between the SC and the FC, thus decreasing the possibility that there was a significant difference in the mathematical knowledge of students in each class prior to the course. To further support the mathematics achievement findings of this study, future research should consider utilizing a pre-course measure of mathematics achievement related to the concepts of the course.

An additional limitation was the substantial difference in the percentage of students who completed the MARS-R survey for the two classes. While 80% of the FC students (28 of 35) had a paired pre/post-course survey, only 56% (15 of 27) of SC students had a paired pre/post-course survey. More of an issue may be that 35 of the original 38 students in the FC (92%) and 24 of the original 29 students in the SC (83%) completed the pre-course survey. This significant drop from the pre-course to the post-course survey in the SC may have influenced the differences in mathematics anxiety between the two classes. It is possible that students in the FC felt more invested in the course, thus they may have been more likely to complete the final survey. Future research should continue to examine the potential influence of the flipped class on mathematics anxiety by using more sections, thus providing a larger sample size for survey collection.

This study examined mathematics anxiety only on a short-term basis. Future research may consider how to examine the long-term influence of content courses and different instructional approaches on mathematics anxiety. In addition, if students are required to complete multiple courses, research may also examine the influence of how multiple flipped class experiences influence mathematics anxiety, achievement, and even instructional practices once the preservice students begin teaching.
The flipped classroom approach provides a unique opportunity for learning mathematics both in and out of the classroom. The combination of a significant decrease in mathematics anxiety with the significantly higher course grades suggests that the flipped classroom may provide the positive learning experience needed to help students feel more confident about mathematics and their ability to teach mathematics within their classrooms. Teachers with lower mathematics anxiety and greater mathematics teaching efficacy have the potential to provide successful learning opportunities for students and thus keep them from forming mathematics anxiety. As one FC student summarized on the survey, "Now that I have taken this class, I think I can handle teaching elementary mathematics. I have a good grasp on how to break things down for students and help them work through the problem step by step."

5. References

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