WHEATON COLLEGE GRADUATE SCHOOL

FLIPPING THE CLASSROOM:

AN EXPLORATION OF THE EFFECT OF INVERTED LEARNING ON STUDENT ACHIEVEMENT IN A HIGH SCHOOL MATHEMATICS CLASSROOM

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by

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Flipping the Classroom:

An Exploration of the Effect of Inverted Learning on Student Achievement in a High School Mathematics Classroom

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Disclaimer

The views expressed in this action research paper are those of the student and do not necessarily express the views of the Wheaton College Graduate School or the Department of Education.

Abstract

This study sought to investigate the relationship between the flipped classroom and student learning. The purpose of this study was to determine if the technique of a flipped classroom, in which initial learning is done outside of the classroom and practice is done within the classroom, contributed to greater gains in student learning. There was one main question researched in this study: Do students in a flipped classroom show evidence of increased learning compared to those in a traditional classroom? The research was performed at a private Christian suburban high school with 25 students over a 4-week period. Data were collected using a pre-test and a post-test design and subsequently analyzed using independent-samples *t* tests. The results showed that while there was no statistically significant difference in gain scores between the control and experimental groups, the raw scores showed positive results in favor of the flipped classroom. The raw data produced other interesting trends, such as the fact that females seemed to respond better to the flipped classroom model than males and that the bottom and top third of the experimental class had higher gain scores than the control classroom. However, in order to investigate these phenomena and the overall effectiveness of the flipped classroom in secondary education, more research should be done.

Keywords: flipped classroom, inverted learning, cooperative learning, high school math, student learning, technology

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Classroom environments play a central role in how students learn; environments that are learner, knowledge, assessment, and community-centered help optimize student learning. According to the National Research Council, some students walk into the classroom with preconceptions about their own intelligence (Bransford, Brown, Cocking, & National Research Council, 2000). These students are more likely to be motivated by performance rather than learning, which translates to an inability to persevere when challenges arise in the classroom. Thus, teachers must develop an environment that is learner-centered in order to monitor progress of each student and devise tasks that are intellectually appropriate. Additionally, an optimal classroom environment is knowledge-centered, meaning that attention should be given not only to the material that is taught, but also to why it is taught. Environments that promote student understanding will facilitate metacognitive learning beyond simple memorization. To test for understanding, teachers must design assessments that help all parties in the classroom gauge progress and understanding. Assessments should be created that help students identify gaps in understanding in addition to providing opportunities to review and expand thinking. Learning is also influenced heavily by the context in which it takes place. A community-centered environment that has students involved in cooperative problem-solving activities promotes intellectual companionship. By creating a classroom that has these characteristics, a teacher can adequately and appropriately challenge students in their learning (Bransford et al., 2000).

Because there are many different types of learners in a classroom, it is important for a teacher to be able to create lessons that cater to the needs of the students. One of these ways is to create an active learning environment that encourages cooperative and collaborative work among groups of students. This type of student-centered learning looks primarily to the theories of Piaget and Vygotsky. In collaborative situations, students ideally learn from one another, talking through and processing concepts that might otherwise be too difficult on their own. Foot and Howe (1998) characterized cooperative learning using the following features: (1) Students work together to achieve a goal, (2) work is divided among team members so that each person is responsible for a smaller goal, and (3) contributions from each individual are collected into a final cooperative product (Topping & Ehly, 1998). Cognitive-development theory, championed by Jean Piaget, views cooperation between people as an essential element for cognitive growth. For Piaget, cooperative learning takes place during healthy socio-cognitive conflict, which in turn leads to cognitive disequilibrium. It is during these times that people work cooperatively to come to precise conclusions.

In addition to Piaget, Vygotsky believed in the fundamental role that social interaction has in cognitive development. By collaborating with peers, one is more likely to understand and solve problems that lead to stimulating intellectual growth (Johnson, Johnson, & Smith, 1998). Among these theories and others, including social-learning theory and behavioral-learning theory, is the idea that learning is powered by motivation, whether intrinsic or extrinsic. Additionally, learners are motivated when they can see the benefits of what they are doing; students who can use their learning inside of the classroom to impact their life outside of it will be more likely to show interest and excitement (Bransford et al., 2000). Therefore, it is imperative that teachers make good connections between material inside of the classroom to how it can be used to benefit people and communities outside of it. By incorporating elements of active learning through the flipped classroom approach, rather than relying on the traditional methods that promote passive learning, teachers can completely transform their classrooms.

So, what is the flipped classroom? Perhaps the simplest definition comes from Lage, Platt, & Treglia (2000): “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). The flipped classroom then can be divided into two main categories: the group learning activities that take place inside the classroom (which are usually interactive and collaborative) and the direct instruction that takes place outside the classroom in the form of online learning. While there can be many definitions of a flipped classroom, it is important to note that for the purpose of this paper, a flipped classroom embodies the above descriptions. With the proliferation of student access to online material as well as the increased convenience of information online, new ways of learning have penetrated many classrooms (Lage et al., 2000). Many online sites provide resources for educators to flip their own classrooms. However, due to this new and quickly growing area of research, not much academic literature is available on the topic of the flipped classroom; the research that is available is limited to cases in higher education and very little is documented in the secondary education classroom (Schultz, Duffield, Rasmussen, & Wageman, 2014).

Therefore, in order to test these ideas, a study has been designed to determine if enhanced student learning occurs in a high school mathematics classroom that employs the ideas of a flipped classroom. Do students learn better when direct instruction is conducted primarily outside the classroom as opposed to inside of it?

Literature Review

The Common Core State Standards present a vision of learning that promote a rich sense of understanding in students, encouraging academic syntax and discourse while challenging educators to provide environments that facilitate hands-on and interactive learning (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). This model, however, stands in sharp contrast to the traditions of lecture-based classrooms across the United States (Moore, Gillett, & Steele, 2014). The solution? A flipped classroom. Originated by Erik Mazur, a Harvard University physics professor in the early 1990s, the idea of inverted learning has gained recent traction thanks in part to the efforts of two high school math teachers, Bergmann and Sams. In the fall of 2009, in the midst of budget cuts and a shortage of financial capital, the two math teachers decided to create their own curriculum and use online resources, thus eliminating the need for textbooks. At first they started small, but eventually it spread to all math classrooms in the Minnesota public high school (Fulton, 2012). Today, other online initiatives are seeing continued growth, such as Khan Academy, which began in 2006. There has been extensive research on how people learn and the best ways in which to appeal to students with different learning styles; the newest idea emphasizes the technique of inversion (Bransford et al., 2000; Lage et al., 2000; Millis, 2002).

In an article appropriately titled, “The Flipped Classroom…: Fad or the Future?” the authors look at the implementation of the flipped classroom into high school classrooms and what it means for student engagement and learning. Jacot, Noren, and Burge (2014) asserted that essentially, the flipped classroom should be understood as a way to best maximize classroom time with students. With this mindset in place, the general roles of teachers and students change. Because students are responsible for learning the material, there is a natural shift between passive learning in the classroom to active, self-directing and self-assessing learning. Additionally, because students have access to material beforehand, they are more likely to move beyond the lower end of Bloom’s taxonomy as they pursue levels of higher order thinking, analyze new concepts creatively and learn to make practical applications of the content they learn (Jacot et al., 2014). By focusing on learning that targets knowledge gain and comprehension outside of class, the lower levels of Bloom’s taxonomy, students are able to focus on grasping the higher levels of application, analysis, synthesis and evaluation with scaffolding from their teacher and through cooperative learning with their peers (Bonwell & Eison, 1991). Furthermore, constructivist theory parallels the ideas of the flipped classroom well. Piaget’s constructivist theory undergirds much of this approach to inverted learning—learners generate knowledge from their interactions between both their experiences and their ideas (Bransford et al., 2000). Collaborative learning, hands-on tasks, group activities, and case studies are indicators of constructivist ideology and characterize the method of inverted learning. While there is still much to be discovered regarding both the successes and failures of the employment of a flipped classroom technique, there is enough research currently to advocate the usage of such a way of learning.

Active and Collaborative Learning

While there is examination of student attitudes and performance in regards to the flipped classroom approach, there is also extensive research on the benefits of active versus passive learning. By definition, active learning is any instructional method that engages students in the learning process (Bonwell & Eison, 1991). In practice, active learning appeals to the higher levels of Bloom's taxonomy, including tasks such as analysis, synthesis, and evaluation (Bonwell & Eison, 1991). Using an approach other than traditional lecture (or modifying the lecture to include elements of active learning) can serve a greater range of students who learn from different pedagogical styles. In contrast, students become passive learners when they are expected "to record and absorb knowledge" (McManus, 2001, p. 426). While active learning classrooms are environments that encourage students to take responsibility for their learning, the instructor in a passive learning classroom merely informs students of what they are to know—students then simply regurgitate information on an exam. Thus, it is easy to see that some of the core elements of student learning involve student activity within in the classroom, which naturally promotes an environment of active learning.

Along with active learning, collaborative learning is an integral part of the flipped classroom. In this way of learning, students are consistently instructed to work together to come to concrete conclusions about the various problems they face. Much research has been conducted on the effectiveness of a collaborative classroom environment and its relationship to student learning. Furthermore, collaborative and cooperative learning helps students develop social skills, as students are required to communicate effectively with one another in order to be successful (Davidson & Worsham, 1992; Goodwin, 1999). An essential component of the flipped classroom, collaborative learning manifests itself through group work, in which students are divided into teams and expected to work together. Elizabeth Cohen (1994), in her book entitled *Designing Groupwork: Strategies for the Heterogeneous Classroom,* laid out a variety of techniques for how to organize groups so that students are challenged by each other and the work that they do together. Most importantly, she wrote on how to make collaborative learning effective, saying that it is the teacher's job to create problems that are challenging and have to be solved by more than one group member. The subject of mathematics is challenging for many students, and collaborative learning, specifically in the context of a flipped classroom, allows even struggling learners to succeed. For, it is within a cooperative environment that students can see the benefits of healthy struggling with mathematical concepts (Hiebert & Grouws, 2007).

Millis (2002) held that as an ideal result of cooperative learning, learning can be deepened; students will enjoy coming to class; and, through practice, students will come to respect and value the individual contributions of their classmates. In a particular study, Lumpkin, Achen, and Dodd (2015) investigated student perceptions of active and cooperative learning as they impact their understanding. Students were given exploratory writing assignments, which led them to deeper thinking on the topic before class. After the teacher lectured, students discussed in small groups the new concept learned and then were asked to write about what they had gained from the class. The students were placed in small groups in class, which were specifically designed to challenge their understanding of content, help them review material already learned, and provide an environment that differed from the norm and contributed to active learning opportunities.

The results of the study were generally positive, as students reported that the exploratory writing assignments were helpful in developing critical thinking skills.

Student Responses to the Flipped Classroom

Researchers are finding that the flipped classroom leads to strong student satisfaction and enhanced learning. With both large and small sample sizes, it has been shown that students are responding positively to the inversion of learning through the use of podcasting, whether in video or audio form. There has been research of student satisfaction across a range of disciplines, usually with a focus on the sciences. Some of the disciplines include statistics (Strayer, 2012), nursing (Hawks, 2014) and economics (Lage et al., 2000). The purpose of much of the research available is to assess student behavior related to the flipped classroom approach as well as student attitudes and performance across disciplines (Alpay & Gulati, 2010; Bolliger, Supanakorn, & Boggs, 2010; Chester, Buntine, Hammond, & Atkinson, 2011).

Because of the rapid growth of distance education, or online learning, educators need to rethink pedagogical practices in order to reach the newest generations of students. However, the *distance* in distance education can be isolating and detrimental to student learning, so technology must be used in a way to promote learning in a cooperative community-centered environment. With the variety of types of media, educators can more aptly reach students with different learning styles, catering to learners of varying abilities in a way that has not been possible until now. An underlying basis for good instruction comes from the theory of motivation. Students and learners of all ages are motivated when they can see the practicality of what they are learning (Bransford et al., 2000). This psychological attribute entices people to learn and is an essential factor in sustaining students' satisfaction in online courses (Bolliger et al., 2010). One study investigated the extent to which students were motivated with the use of podcasts in an online environment. In a survey at the end of the course, students generally reacted positively to the experience, saying that convenience of the podcasts contributed greatly to their learning. Overall, the study showed that students were motivated by the use of podcasts in their online courses (Bolliger et al., 2010).

In another study, engineering students were in charge of the entire "operation," from the creation to the distribution of the podcasts. The purpose of this strategy was not only to promote experiential learning for the students, but also to foster student motivation and support active engagement among peers and faculty. This student-led podcasting initiative functioned as an important development and resource for students and faculty of the engineering department at a particular university in London (Alpay & Gulati, 2010). The purpose of this research was both to assess satisfaction among students who used the podcasts and also to compare the academic behavior between podcast users and non-users across disciplines.

While much of the literature reports the positive effects of the flipped classroom, a study conducted by Lape et al. (2014) concluded that student learning in the flipped classroom showed no significant difference to student learning that occurred in the control classroom. In this study, the researchers wanted to determine if students showed higher learning gains in the experimental classroom, in addition to collecting data about the attitudes of students toward the flipped classroom. Their analysis showed that the there was no significant difference between the two classes, and that the control group even had lower pre-test and higher post-test scores (overall, higher gain scores) than the experimental group. Additionally, there was a mixture of responses to the inverted style of the classroom, with students having strong opinions on both ends of the spectrum.

Furthermore, a particular finding of interest in another study was the level of attendance of the students in the classes; by Week 8 of the course, there was only 50% attendance. Additionally, students who attended classes every week were significantly less likely to use the podcasts as supplementary material, whereas students who reported never coming to class used the podcasts regularly. In the case of this study, the inverted classroom strategy actually decreased student attendance, and researchers found that there was an inverse relationship between attendance and podcast usage (Chester et al., 2011).

The Flipped Classroom in Secondary Education

In a secondary education context, Schultz et al. (2014) performed research to determine if there was a statistical difference in academic performance between the control group, who experienced a traditional lecture approach, and an experimental group, who experienced a flipped classroom approach. Both groups were AP Chemistry classes in a high school environment in two different school years. In the flipped classroom approach, students watched a video at home and then were asked to complete a post-video reflection guide, which served as a formative assessment. In class, the teacher would review questions at the beginning, but the bulk of the class period was spent working through book problems or learning through the use of a variety of activities. The researchers concluded that the creation of a student-centered learning environment (by way of the flipped classroom approach) enhanced student learning. Furthermore, the researchers attributed the enhancement in student learning to three main areas: (1) Students were in charge of their own learning; (2) students had more than one opportunity to learn the material; and (3) since direct instruction was moved outside of the classroom, there was more time for teacher support within the classroom. An interesting result from this study was the fact that male students consistently performed better than female students as a result of the flipped classroom approach, a statistically significant result that was shown through an analysis of score differences between both classrooms.

Another study, conducted by a student teacher in collaboration with her cooperating teacher, wanted to determine if the flipped classroom improves student ability in analyzing linear equations, a specific subset of a middle-school algebra class (Kirvan, Rakes, & Zamora, 2015). The research study was completed over the course of one unit. In the control classroom, students received guided notes to assist them in their learning and the teacher emphasized conceptual understanding as an important learning gauge. In the experimental classroom, direct instruction occurred at home through online instructional videos; students were instructed to complete a guided notes sheet, the same one given to the control classroom participants, as they watched the video. When students came to class the next day, they were given a pre-assessment and then divided into two groups, the exploration group and the re-teaching group, based on their performance. The researchers concluded that the flipped classroom showed strong improvement in students' abilities to solve linear equations, but reported that it "did not necessarily increase focus on conceptual understanding without explicit attention to the substance of the videos and in-class activities" (Kirvan et al., 2015, p. 217). While the researchers concluded that there were positive effects of the flipped classroom, it is interesting to note their observation that it did not necessarily increase solid conceptual understanding in their algebra students.

Research Question

Using the research as a basis, this study seeks to determine if implementing a flipped classroom approach enhances student learning in a high school mathematics classroom. In this study, the researcher seeks to answer the following question:

- Do students in a flipped classroom show evidence of increased learning compared to those in a traditional classroom?

Because of the increase of technology within the school setting, this study will look at ways in which technology can be used to enhance student learning in the flipped classroom. Through the implementation and results of this study, educators can be more informed as to how to best meet the learning needs of their students in the classroom.

In this study, the independent variable is the implementation of different teaching techniques (flipped classroom vs. traditional lecture-based classroom), and the dependent variable is the students' performance from the pre-test to the post-test assessments (gain score). Research has shown that there is an increase in student learning, which will be measured using gain percentages between pre- and post-tests, when students have the opportunity to participate in active learning within the classroom (Bonwell & Eison, 1991; Lumpkin et al., 2015). Because the flipped classroom lends itself more naturally to an active learning environment, this research study seeks to investigate the effectiveness of such a technique. If proven to be effective, then the flipped classroom is another, extremely innovative way through which mathematics educators can engage their students in learning.

Methodology

Context

This research was performed at a relatively large (~400 students) private Christian high school in the suburbs of a large midwestern city. The majority of students were Caucasian (74%); 15% African American, 6% Hispanic, 3% International students, and 2% Asian made up the rest of the student population. The school was located in a wealthy suburb, and students had traditionally performed well on state and national tests. In 2014, students scored an average of 4 points higher (24.6) on the ACT composite score compared to composite scores across the state the same year (20.7). Additionally, U.S. News and World Report recognized the school as one of 96 "Outstanding High Schools in America." During the 2014–2015 year, the school implemented one-to-one iPad technology. Furthermore, each classroom is equipped with SmartBoards and students have access to a variety of educational technologies.

Subjects

The subjects in this study were 10th- and 11th-grade students enrolled in two sections of Honors Pre-Calculus, the typical course sequence for students in the honors tracking in the high school. For some of the students, this will be the last year of mathematics credit the school requires; however, the majority of the students will continue onto AP Calculus during their senior year. Because of the lack of flexibility in scheduling, the subjects in this study were selected for the sake of convenience—the distribution of students, in regards to GPA, was similar. Because the researcher was dependent on administrative choice and scheduling, she could not change the distribution of gender in each classroom; the students were chosen quasi-randomly. In the traditional lecture-based classroom, a total of 12 students participated in the research (8 female, 4 male). In the flipped classroom, 13 students participated (5 female, 8 male). Each Honors Pre-Calculus class was composed of approximately 15–20 students.

Method

Due to the fact that true randomization of subjects was out of the control of the researcher, a quasi-experimental design was implemented in the two classrooms. One classroom was randomly selected to participate in a flipped classroom intervention technique (experimental group) for a singular unit on rational and polynomial functions, meaning that students will use technology to assist in their learning outside of the classroom and will participate in specific instructional techniques inside the classroom. The second classroom served as the control group and experienced a traditional classroom approach for the same unit, with instruction taking place inside of class and independent practice occurring outside of class.

For the flipped classroom, the researcher created short videos (~10–12 minutes) using an iPad app called "Explain Everything" to produce and upload video lectures to an online site that students were able to access from home. Students were required to watch the videos and take notes in addition to answering questions (or asking questions) about the content as the video progressed. These "quizzes" served as formative assessments and students were given a grade based on their completion of the video and not the accuracy of their answers to the questions. The purpose of the quizzes was two-fold: (1) to encourage students to complete the videos *before* coming to class and (2) to give the researcher information about where students need further explanation. When class began, the researcher answered questions and reviewed concepts before giving students the opportunity to work together in small groups to complete problems, assignments, or educational activities that reinforced the content that had been explained via video. Students were placed in groups based on test scores from the previous unit. In order to determine which students were in each group, the researcher used a ranking system. In each group, there was a high-performing, low-performing student and two middle-performing students. The purpose of this grouping was to evenly spread out the students, so that no group would be more or less advantaged. Because the majority of the "lecture" was completed outside of class, students had more opportunities to ask questions and work together with their peers to come to more concrete understandings of material. Activities that strengthen understanding took the place of traditional lecture within the classroom, and assignments traditionally assigned as homework were completed within the context of the classroom. Students remained in their same groups for the entire unit, thus allowing them the opportunity to form relationships with each other and feel comfortable succeeding, or failing, together.

The activities in the flipped classroom were developed by the researcher in order to reinforce the concepts that were learned in the video the night before. A variety of methods were developed. For example, the researcher created a matching game so that students could determine the various aspects of a rational function. Students were given a worksheet to fill in their answers from their matched cards, which served as a hands-on note-taking tool. Furthermore, the researcher developed a game that required each member of the group to work together so that a puzzle could be successfully completed. In each of the activities, the students were solving the same type of problem approximately 10–20 times, which served as a way to further reinforce the concept. These students were able to take advantage of both peer and teacher presence in order to come to a more complete understanding of the material.

In the second classroom (the control group), the teacher lectured on the same content and students were able to use the knowledge gained in class to complete assignments outside of class. Following the model of a traditional mathematics approach, which was not different than the way the researcher taught the previous unit, students had the opportunity to engage in lecture within the classroom. By way of this approach, students had time to complete practice problems during the guided practice portion of the lecture period, but the majority of independent learning occurred outside of the classroom through homework problems. These problems were generally the same in both classrooms, but the students in this second classroom completed them outside of class rather than inside. Students were graded on their completion of these problems and not on the accuracy of their answers. Educational activities or supplemental technology were not completely absent from the context of this classroom, and the researcher made an effort to include students in learning via technology and other hands-on activities; however, due to time constraints as posed by the traditional approach, hands-on activities were less frequent than in the flipped classroom. When time allowed, students in the control classroom were given the same activities and thus were not deprived of some of the possible advantages of their peers in the experimental classroom.

All students were given a pre-test before the unit on rational and polynomial functions, which measured skills that were going to be taught during the duration of instruction. The pre-test was composed of four questions that were representative of the material covered throughout the unit. The general outline of the assessment used was obtained from the researcher's cooperating teacher; however, the researcher was given the freedom to create her own assessments. The pre-test was not included in the students' final course grade, but the post-test was embedded in the formal, summative assessment that was administered at the end of the unit. The pre-test mirrored the content that was assessed in the summative assessment at the end of the unit; two of the four questions were identical from pre-test to post-test, while the other two questions tested the same concept though were not identical problems. The researcher gave both tests on the same day in both classes.

The data collected from these tests were used to analyze the null hypothesis that there is not a significant difference between the groups who received flipped classroom instruction and those who received instruction by way of the traditional approach. The research hypothesis was that students who receive flipped classroom instruction would show increased learning as evidenced by a higher gain score. Statistical analysis was conducted using a two-tailed paired-sample *t* test in order to test for significance between pre-test and post-test scores in both classes. Furthermore, in order to determine if there was significant difference in the type of intervention implemented, an independent-samples *t* test was conducted on the gain scores from pre-test to post-test between the control and experimental groups. A rejection of the null hypothesis would show that there is a significant difference in the gain scores between the two groups and the researcher would be able to conclude that the flipped classroom intervention was successful in increasing student learning. In order to get the most complete view of the data collected, the researcher performed additional independent-samples *t* tests in order to compare gain scores across gender and to investigate the success of the intervention between high- and low-achieving students between classes. In summary, both paired-samples and independent *t* tests were implemented, which allowed the researcher to compare not only mean scores within the classes, but also the gain scores between classes. All calculations were computed using Statistical Package for the Social Sciences (SPSS).

Both the experimental and control groups had incomplete data for a variety of reasons. When the pre-test was administered, there were students in both classes that were absent. Because the new unit began the next day, the absent students were not allowed to make up the pre-test, which could lead to a compromise of the data due to exposure. Thus, these students' post-test scores were not included in the final data analysis, which then could have had an impact in the overall determination of whether or not the flipped classroom implementation was successful. As a result, one student's score in the control group was disregarded, leaving 12 students involved in the study, ($n = 12$), and six students' scores in the experimental group were disregarded, leaving 13 students ($n = 13$).

Results

Before establishing whether or not there were statistically significant differences in student gain percentages between the two classrooms, the researcher first determined if there was significant difference between the pre- and post-test scores within each classroom. Table 1 and Figure 1 show a summary of the data findings.

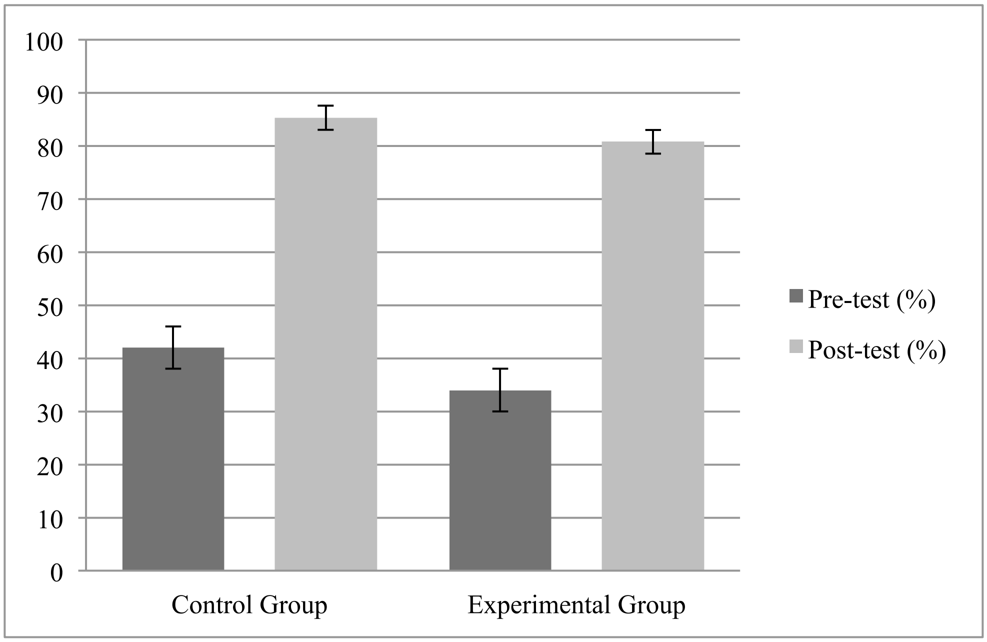

Figure 1. Mean pre- and post-test scores and standard error for control and experimental groups.

Table 1

Percent Change (Gains) in Scores on Pre- and Post-Tests

		Pre-test (%)		Post-test (%)		
Group	*n*	*Mean*	*SD*	*Mean*	*SD*	*t Value*[a]
Control	12	42.0	17.3	85.3	11.1	-8.2*
Experimental	13	34.0	21.8	80.8	14.0	-8.9*

[a]Two-tailed paired-samples *t* test from pre- to post-test.

*$p < 0.001$.

From the data displayed in Table 1 and Figure 1, it is easy to see that there is significant difference ($p < 0.001$) in the mean scores between pre- and post-tests in both the control and experimental groups. This result is not surprising, because students had no previous exposure to the material and thus would be expected to progress regardless of the technique the teacher used in relaying the information. Additionally, this analysis shows that the researcher was relatively effective in her teaching, as students saw significant improvement in scores.

Pre-Test Scores

It is interesting to note that the control group scored higher on the pre-test (42%) than the experimental group (34%), but statistical analysis using an independent-samples *t* test shows that the differences between the two classes are not significant ($p = 0.33$). The low percentages in both classrooms indicated that while students had some background knowledge of the material to be covered in the unit, it was obvious that they were not proficient in their understanding. While there were some outliers (i.e., some students scored significantly higher or lower than the mean score) in both classes, they did not overly skew the data.

Post-Test Scores

In analysis of the post-test scores, it is again interesting to note that the control group scored higher on the post-test (85%) than the experimental group (81%). However, after statistical analysis using an independent-samples *t* test, the difference exhibited in the raw scores between the two groups is not significant ($p = 0.39$).

Gain Scores

For the purpose of this study, the majority of statistical data analysis looks at the gain percentages between the control and experimental groups. This process is done so that the researcher can more effectively answer the research question of whether or not there was significant increase in student learning in the experimental classroom. While the experimental group showed lower pre-test and post-test scores than the control group, the gain scores for the experimental group (47%) were greater than the control group (43%). However, an independent-samples *t* test yielded that there was no statistically significant difference between the gains of the two groups ($p = 0.66$). Table 2 and Figure 2 outline the results.

Table 2

Pre- and Post-Test Scores for Control and Experimental Groups

		Pre-test (%)			Post-test (%)			Gain (%)		
Group	*n*	*Mean*	*SD*	*t Value*[a]	*Mean*	*SD*	*t Value*[a]	*Mean*	*SD*	*t Value*[a]
Control	12	42.0	17.3	1.01	85.3	11.1	0.89	43.3	18.3	-0.47
Experimental	13	34.0	21.8		80.8	14.0		46.8	18.9	

[a]Two-tailed independent-samples *t* test.

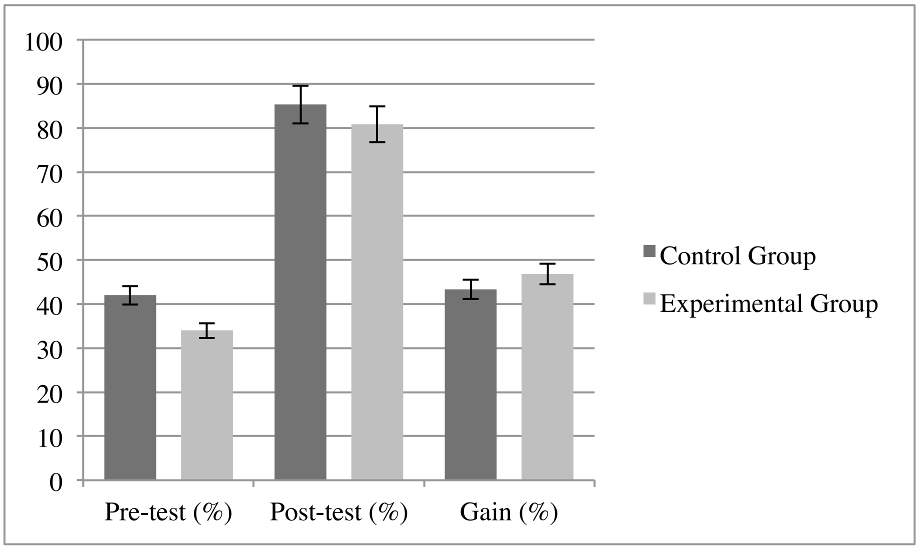

Figure 2. Mean scores for pre-test, post-test, and gain for control and experimental groups with standard error.

Differences Among Subsets of Students

While there was a not significant difference in the gain scores between the control and experimental groups, it is interesting to note the impact the flipped classroom had on gender and on students who are considered high-achieving or conversely, low-achieving. While there does not currently exist specific research that looks at the differences in learning among students on different achievement platforms, it has been shown that when students have the opportunity to engage with their peers, they are more likely to report increased levels of satisfaction, which could lead to an increase in learning (Bransford et al., 2000). Furthermore, dividing the control and experimental groups based on gender could yield some different conclusions on whether or not the flipped classroom was a successful technique.

The data displayed in the Table 3 and Figure 3 leads to some interesting conclusions, though none are statistically significant. In the control group, both males and females had the same percentage gain scores between pre- and post-tests, at 43%. Interestingly, between groups, the males in the control group had a higher percentage gain than the males in the experimental group; however, this difference is not significant. Among females, the data are more striking. In the experimental group, there was a wider percentage gap (17%) between males and females in gain scores, with males gaining an average of 40% and females gaining an average of 57%. Between groups, the females in the experimental group experienced a 14% gain over their female counterparts in the control group, though again, this difference is not statistically significant.

Table 3

Comparison of Male and Female Performance in the Control and Experimental Groups

	Control			Experimental			
	n	*Mean*	*SD*	*n*	*Mean*	*SD*	*t Value*[a]
Male Gain (%)	4	43.27	24.00	8	40.39	13.48	0.27
Female Gain (%)	8	43.27	16.67	5	56.92	23.30	-1.24
t Value[b]		0.00			1.03		

[a]Two-tailed independent-samples *t* test. [b]Two-tailed independent-samples *t* test comparing means of males and females for control and experimental groups.

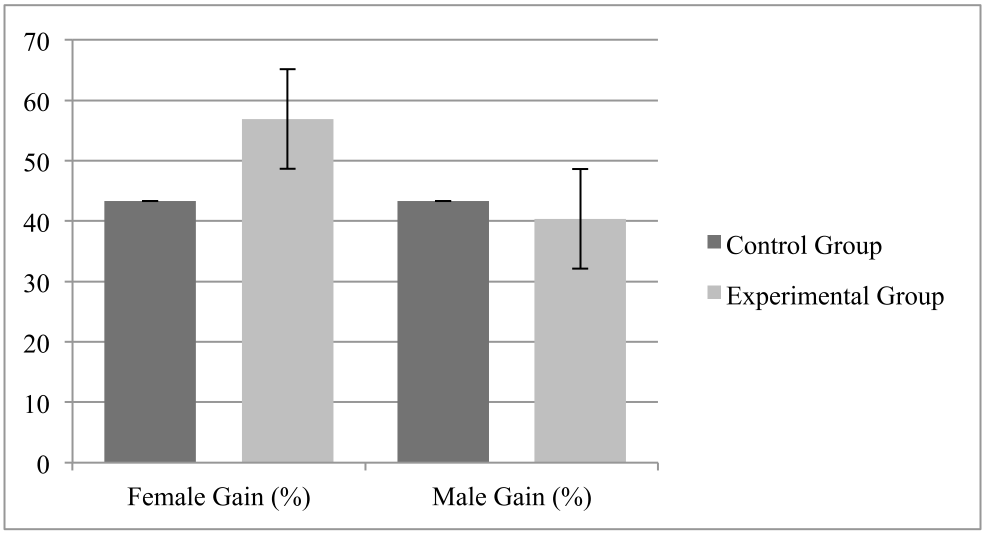

Figure 3. Gain percentages for males and females with standard error.

When comparing students in the bottom and top third of the class, based on their performance on the pre-test that was administered at the beginning of the unit, there is an interesting data trend. Before the experiment began, the researcher took note of the semester grades of both the experimental and control groups. In both groups, the mean score was almost exactly the same; the mean score for the control group was 90.24%, while the mean score for the experimental group 90.33%. These scores show that both groups started out with similar foundational content knowledge, an important factor in determining if the instructional technique was successful. An independent-samples *t* test confirmed that there was no statistically significant difference between the two semester mean scores ($p = 0.13$).

In looking at the data in its entirety, it is evident that students in the experimental group, whether in the bottom or top third of the class, saw a higher percentage gain than their peers in the control group. To determine which percentile group students fell into, the researcher divided the class into thirds based entirely on the student's gain scores. In the control group, students who were considered in the top third gained an average of 28% from pre- to post-test, while students in the top third of the experimental group gained an average of 31%, though this difference (3%) is not statistically significant. Furthermore, students in the bottom third of the control classroom gained an average of 53%, while students in the bottom third of the experimental classroom gained an average of 62%, which calculates to a 9% gain overall between the two groups. From Table 4 and Figure 4 below, it is easy to see that students in the bottom third of the class benefited from the teaching technique in the experimental group, though neither of these results is statistically significant. When the bottom and top third of students were compared with one another in their respective control and experimental groups, the difference was found to be significantly significant ($p = .031$ and $p = .016$ respectively), meaning that the bottom third of the class improved significantly from pre-test to post-test over the top third, regardless of whether or not treatment was administered. However, there is more significant evidence that the gains between the top and bottom third of the experimental group ($p = 0.016$) were different from those of the same groups of students in the control group.

Table 4

Comparison of Top and Bottom Third in the Control and Experimental Groups

	Control			Experimental				
	n	*Mean*	*SD*	*n*	*Mean*	*SD*	*t Value*[a]	*Effect Size*[b]
Semester Grade	12	90.24	7.31	13	90.33	4.77	-0.04	
Top Third Gain	5	28.46	17.33	5	30.77	6.08	-0.28	0.18
Bot Third Gain	5	53.10	11.98	4	61.54	21.07	-0.77	0.49
t Value[c]		2.62*			3.16*			

[a]Two-tailed independent-samples *t* test. [b]Effect size calculated as the difference between the means of the experimental and control groups divided by pooled standard deviation. [c]Two-tailed independent-samples *t* test comparing means of top and bottom third for control and experimental groups.
*$p < 0.05$.

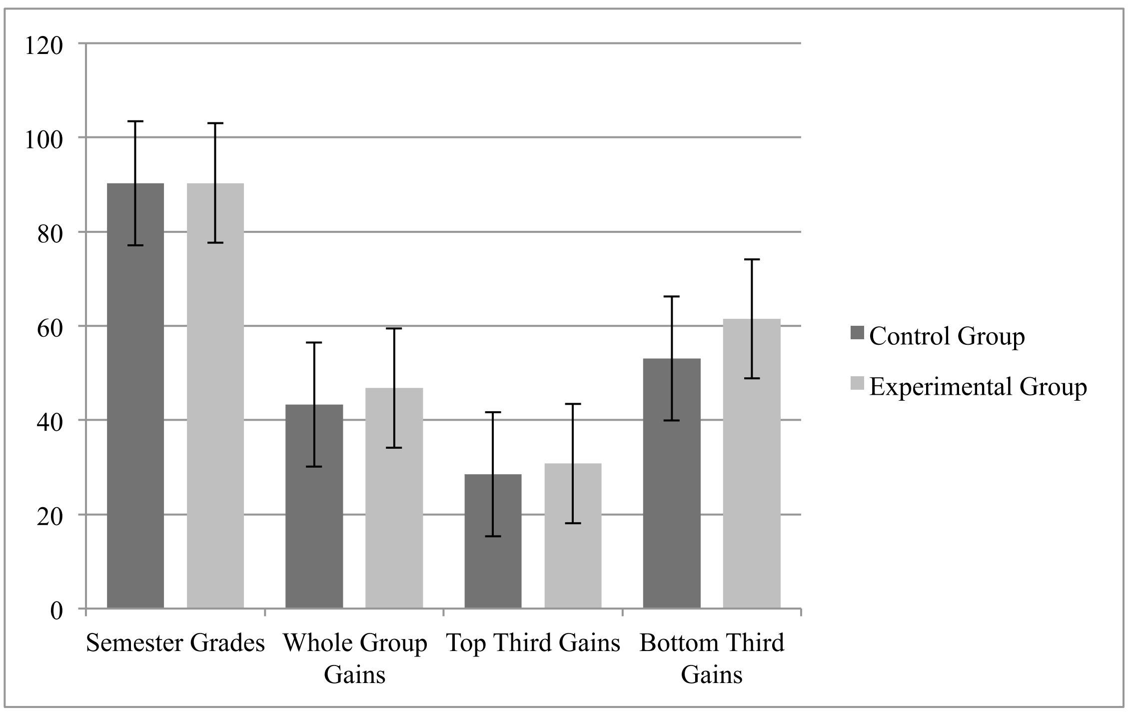

Figure 4. Mean semester grades and gains between student groups with standard error.

Student Responses to the Flipped Classroom

At the conclusion of the treatment period in the experimental classroom, the researcher conducted a survey in order to measure student response to the flipped classroom and as a way to supplement the quantitative data. Results showed that there was a spread of opinions, with some students having strong opinions on both ends of the spectrum. On the survey, students were asked to respond to video clarity, usefulness of in-class activities and group work, and the extent to which the participant liked working with the same group of people every day (see Appendix A). Answers to these statements ranged from strongly disagree to strongly agree, and there were two open-ended questions, which asked students what they liked and disliked about the flipped classroom.

In looking at the results of the survey, 50% of students reported that they agreed or strongly agreed with the statement that the videos were clear in the explanation of the material; 21% answered disagree, with 0% answering strongly disagree. For the second question, 42% of students reported that they agreed or strongly agreed that the in-class activities and group work helped them understand the material better, with 35% reporting that they disagreed or strongly disagreed. When it came to working with the same group of people every day, students were equally split on their approval or disapproval at 42% on both sides.

The open-ended questions gave more insight into student perceptions of the flipped classroom. Many students reported positive aspects of the flipped classroom, and one student wrote, “You knew you had a specific amount of homework time everyday and I think it was usually less time than I would spend on normal homework. Also I liked being able to rewind and rewatch videos.” Another student reported similar feelings of attraction toward the flipped classroom technique: “The fact that there was no homework other than watching the videos and taking notes is attractive. Also, the quizzes typically applied to what we learned in the videos, so most of the time the quizzes were relatively easy.” Additionally, another student reported, “The lectures weren't interrupted by other students being disrespectful or asking personal questions, and we could go through the videos at our own paces” and a couple of students wrote that they appreciate being able to ask questions on concepts while in class, “rather than be stuck at home trying to do it.”

On the flip side, the survey also gave students a way to voice their frustrations with the flipped classroom model. One student reported, “If I didn't understand, it felt like I was just lost and would never get the material, and I didn't really like my group.” Another student wrote that he did not feel motivated in flipped classroom: “I felt we didn't learn the material well. Going home to do the homework and learning on your own is the best way to work. In the flipped class you could rely on others and then when you’re on your own for the quiz you don't know what to do.” Others noted that if they were confused during the video, they were unable to ask questions in real-time, a component that is part of the traditional classroom.

While there was indeed a spread of opinions on the success of the flipped classroom, the results do not deviate from what other researchers have found concerning student opinions on the technique. In this research study, students were introduced to a full classroom flip on the first day of the unit, and thus did not have time to acclimate to the pace and structure of the classroom. For many students, this was their first exposure to a classroom run in this way, a factor that led the researcher to conclude that there could have been a “novelty effect” that skewed some of the results.

Discussion

While these results do not show statistically significant evidence of the flipped classroom leading to an increase of student learning (by measure of gain scores), they are not completely outside the scope of research on the effectiveness of a flipped classroom and its relationship to student learning. Indeed, some studies have reported preliminary findings regarding the negative impact of the flipped classroom on student achievement within the classroom (Lape et al., 2014); however, this conclusion is not consistent with the majority of research that is available on the flipped classroom, and more broadly, the role of active learning in the classroom (Bransford et al., 2000). Upon analysis of the data in this study, it was discovered that there was not significant difference between the control and experimental groups after the implementation of the flipped classroom on a singular unit. However, when looking at the raw scores, it is easy to see that between classes, genders, and achievement levels, the students in the flipped classroom consistently scored higher than their peers in the traditional lecture-based classroom. The flipped classroom treatment, though statistically not significant in this study, has been shown in many research studies across a variety of students and grade levels to be positively effective (Kirvan et al., 2015; Lage et al., 2000; Millis, 2002; Schultz et al., 2014; Strayer, 2012).

Differences From Previous Research

One of the most significant differences between previous research studies and the study documented in this paper is the length of time the treatment was in effect. In many studies, the time frame of the study stretched from a singular semester (Alpay & Gulati, 2010; Bolliger et al., 2010; Lage et al., 2000; Strayer, 2012) to an entire school year

(Schultz et al., 2014). For example, in a study conducted by Alpay and Gulati (2010), undergraduate students in an engineering class were in charge of creating and distributing podcasts to their peers and other faculty members. A survey was conducted at the end of the semester in order to assess student attitudes toward the process. In another study that measured the extent to which students were motivated by the use of podcasts in an online environment, researchers administered a survey at the conclusion of the semester-long class. Furthermore, a study conducted by Lage et al. (2000) specifically investigated the method of the flipped classroom and its relationship to student perceptions in a semester-long study with undergraduate students. Stayer (2009) similarly conducted research in an undergraduate psychology class, where again, students were surveyed and interviewed at the end of the semester. In a study that spanned the length of the school year, Schultz et al. (2014) measured the effectiveness of the flipped classroom in order to determine if there were significant academic differences between students in the control and treatment classes. In all of these studies, the researchers were able to determine that, whether students were using podcasts or involved in a flipped classroom, there was significant difference between students in control and experimental groups.

In this study, the intervention of the flipped classroom only took place over a 4-week period, the amount of time it took to cover a unit on rational and polynomial functions. Based on previous research, this short time span could have had a negative impact on the results, which would lead to the conclusion of nonsignificant results, as students would not have had time to be properly acclimated to the structure and format of the classroom. Strayer (2007) noted in his dissertation research paper a potential “novelty effect,” and suggested that students need to have time to adjust to the new process of classroom instruction. Strayer (2007) went on to say that there could be a potential threat to validity if students are not given enough time to adjust. Due to the limitations placed on the researcher, a longer amount of time to conduct research would have been almost impossible; however, student scores, in addition to student perceptions, may have increased given more time to adapt.

In addition to the fact that one of the main limitations of this study is the length of time, another significant limitation is the small sample size. Because of this limitation, even a relatively large raw data difference would have not shown significance when analyzed statistically. Many studies employed the use of hundreds of students (Bolliger et al., 2010; Chester et al., 2011; Lage et al., 2000) so that even a small deviation in raw data would have been statistically significant. In a study conducted by Bolliger et al. (2010), 302 undergraduate students took part in the survey that was administered at the end of the course. Chester et al. (2011) similarly administered a survey to 288 students, and Lage et al. (2000) drew on the experiences of 200 undergraduate students. In studies that were more similar to the sample size of the study written about here, there were still more than double the number of participants that were a part of the study. Schultz et al. (2014) conducted his study with 61 high school students, and Strayer (2012) had 49 student participants. Again, these studies showed statistical significance when analyzed. Because the researcher of this study was dependent on administrator scheduling and a small school population size as a whole, the amount of students involved was therefore difficult to control. Even though the raw data show that students who were exposed to the flipped classroom model had an overall gain percentage higher than their peers in the control classroom, the sheer number of students led to the conclusion that these differences were thus not significant. Had there been more students, the results might have differed dramatically.

In a study conducted by Schultz et al. (2014), a study that was most similar to the research conducted here, the researcher developed a way for students to be accountable for the information learned via the video. Before coming to class, students were instructed to complete a post-video reflection. According to Schultz et al. (2014), the purpose of these assessments was twofold: (1) accountability and (2) a way for the instructor to informally assess student understanding of the content. In another study, students were given quizzes at the beginning of the period and then were divided into an "exploration group" and a "re-teaching group." A student in the "re-teaching group" had to prove understanding of the material before he or she was allowed to join his or her peers in the "exploration group" (Kirvan et al., 2015). To accompany the video lectures in his study, Lage et al. (2000) provided students with printable notes sheets and Moore et al. (2014) indicated that students had to watch the online video in addition to completing a notes guide. Both of these things were considered homework for students. Unfortunately, one of the limitations to this study is the deviation from these methods of informal assessment. While each student had to answer questions during the course of the video, there was no true consequence for not watching the video or neglecting to answer the questions. Because the quizzes were graded on completion only, there was no way for the researcher to determine if the student really did not understand the concept or was just trying to "get something down" and move on. The lack of a notes sheet, which is in direct contrast to the studies listed above, may have led to a surface-level understanding of the material presented in the video. Furthermore, there was no accountability, an important feature of study conducted by Schultz et al. (2014) and an imperative part of any classroom. While there was a method of informal assessment that was part of the flipped classroom, there was not enough to be able to gauge an accurate understanding of how well, or how little, the students were able to grasp the concepts.

An important aspect of collaborative learning is grouping, and in the course of the study, the researcher consistently placed students in groups of 3–4 so that together, they could come to conclusions about the in-class problems. In nearly every class period, students were assigned to the same groups, a method that is in contrast to at least one other study. In a study conducted by Lape et al. (2014), which surprisingly concluded that the flipped classroom did not lead to academic gains when compared to the control classroom, the researcher allowed students to choose (rather than be assigned to) their own groups of 2–3. Furthermore, other studies have indicated that while group work was an important part of classroom function, not all class activities required groups (Lage et al., 2000; Schultz et al., 2014). Significant study has been conducted on the effectiveness of collaborative learning (Bonwell & Eison, 1991; Millis, 2002), but it is unclear on to the extent of which the researchers relied on students being part of the same group for each activity. Though the mixed-ability groups were strategically set by the researcher at the start of the unit based on semester grades, it became apparent that students held mixed opinions about the effectiveness of staying with the same group throughout the course of the unit. Research that speaks directly to this phenomenon in the context of a flipped classroom is limited, so whether or not inflexible grouping is a true limitation of the study is something that should be examined more in depth.

One of the most important tests in order to determine if a study is valid is to test the validity of the assessments. In the case of this study, the researcher created the pre- and post-tests that students took at the beginning and end of the unit. The fact that these tests were not standardized, nor created by a group of experienced teachers, is another significant limitation in this study. In a study conducted by Kirvan et al. (2015), the main researcher was a student teacher who had assistance from her cooperating teacher. Even in this scenario, the pre-test and post-test administered to students in the algebra class was constructed by a panel of math teachers and pre-tested for validity. Similarly, in a study conducted by Lape et al. (2014) at an undergraduate university, experienced mathematics faculty created the pre-test and post-test questions. This limitation in this study is important to address, because the untested validity of the pre-test and post-test questions could had led to the result of nonsignificant differences between the two groups. Furthermore, while two of the four pre-test questions were mirrored in the post-test, the remaining two were different questions. Though they were testing the same concept, there was no way to know if the post-test question was a valid reconstruction of the concept presented in the pre-test. Again, because the questions were not standardized, they could be invalid measures of conceptual understanding. In the studies conducted by both Kirvan et al. (2015) and Lape et al. (2014), the same pre-tests and post-tests were used. The inconsistency of the study, in specific relation to the development of the pre-test and post-test, could have been part of the reason for the nonsignificant results.

Further Limitations

Much of the research referenced and outlined in this paper took place in the context of classrooms led by experienced high school or university professors (Bolliger et al., 2010; Chester et al., 2011; Kirvan et al., 2015; Lage et al., 2000; Schultz et al., 2014). In the case of the studies led by Bolliger et al. (2010) and Chester et al. (2011), the instructors were experienced university professors. Lage et al. (2000) conducted a study among undergraduate students enrolled in multiple sections of economics, which were taught by two different university professors. Schultz et al. (2014), one of the few studies that was conducted in a high school, is an experienced Advanced Placement teacher. Surprisingly, the researcher in a study entitled “Flipping an Algebra Classroom: Analyzing, Modeling and Solving Systems of Linear Equation” was a student teacher, but she had the benefit of the help of her cooperating teacher, an experienced professional (Kirvan et al., 2015). In each of these studies, the main instructors in the classroom were experienced teachers or professors, or in the case of the Kirvan et al. (2015) study, had significant assistance. For this study, the credentials of the researcher place a limitation on the validity of the study. Through statistical analysis, however, it was shown that students in both the control and experimental classroom experienced significant academic growth between pre-test and post-test. Thus, it can be assumed that the researcher was relatively effective in her teaching, even though her age and experience can be considered a difference, and thus potentially a limitation, between previous research studies.

One final limitation to this study worth mentioning is the unequal spread of gender and the possibility of the unequal spread of ability between the control and experimental groups. In one study, analysis proved that students in both the control and experimental groups “were well-matched in terms of theoretically relevant demographic and background information” (Lape et al., 2014, p. 5). Another study reported equal or near equal numbers of male and female participants (Strayer, 2012). One study in particular reported an interesting result in the conclusion of the paper: After data analysis, it was discovered that male students performed better as a result of the flipped classroom when compared to their female peers (Schultz et al., 2014). Though the sample size was small, a limitation that the researchers address, the gender distribution is relatively equal. This gender distribution is a difference from the study written about here, for the control and experimental groups were unequally weighted in terms of gender. While not believed to be an influencing factor, it is important to note that this factor is a difference from previous research studies, which showed significant evidence in the difference in academic performance between students in traditional lecture-based classrooms and flipped classrooms.

Analysis of Results

In order to answer the research question about student academic growth based on the treatment of the flipped classroom, the researcher looked specifically at gain scores, defined as the difference in scores between the pre-test and post-test. In all cases in the control and experimental groups, students had higher post-test scores than pre-test scores, a result which was shown to be significant. While this result does not answer the research question directly, it does indicate that the researcher was effective in teaching, as both classes grew significantly, regardless of treatment. However, it was determined that though the experimental group showed more growth (by measurement of gain scores from pre-test to post-test), the difference between the two groups was not significant. The raw numbers show that there were differences in gain scores between the two groups (the control group had a mean gain score of 43% and the experimental group had a mean gain score of 47%), but statistical analysis shows no significance in this difference.

At the beginning of the study, both groups were statistically equal—both the control and experimental groups had the same semester grades up until that point. This characteristic is important, because it shows that both the control and experimental groups, even though they were not chosen at random, were relatively similar. It is interesting to note that the pre-test and post-test scores were higher in the control group, though this difference is not significant.

Albeit not significant, a variety of factors could have led to an increase in the gain scores of the experimental group that is shown in the raw data. First, the flipped classroom allows for a collaborative learning environment where students could interact and converse with their peers. Because students had access to content ahead of time, they were then free to reach higher levels of Bloom's taxonomy as they conversed, struggled, and analyzed mathematical concepts with their classmates. In this way, the classroom became a learner-centered environment, and the teacher was no longer a "sage on the stage," but rather a "guide on the side." The flipped classroom lends itself naturally to this mindset, and it gives students the opportunity to struggle together instead of alone. Indeed, Hiebert and Grouws (2007) wrote about the importance of struggle as students try to make sense of mathematics. Struggle, as they set out, is not a needless activity that ends in desperation or frustration. Struggle should not produce feelings of despair in a student; rather, healthy struggle allows students to "figure something out that is not immediately apparent" (Hiebert & Grouws, 2007, p. 387). It is this precise method of struggling that the flipped classroom promotes—students are forced to work through difficult concepts on their own and with their peers. Thus, in this environment, mathematical growth and conceptual understanding is achieved.

Additionally, the use of heterogeneous mixed-ability grouping gave students the opportunity to develop social skills and served as a means of structure to promote positive interdependence among students. It was in this environment that students in the flipped classroom thrived, as many saw the benefits of grouping in this way. Central to collaborative learning theory is the idea that working together fosters both team and classroom building (Davidson & Worsham, 1992). Within each team, there were natural leaders and followers, but because of the variety of activities that were given during the course of the unit, the team learned to work together and share in each other's successes and failures. Many activities required that the entire group be able to show competency in the content before moving on to another topic. Overall, the students in the flipped classroom had a unique opportunity to continually converse with their peers and struggle with the concept together, thus leading them to greater overall understanding.

Another factor that could have led to an increase in gain score among the experimental group were the intentional hands-on activities and use of graphic organizers that were designed to assist students in learning mathematical concepts and developing conceptual understanding. Many of the activities required completion by a group or pair of students, as solving the problem or puzzle proved too challenging for one person. Cohen (1994), in her book entitled *Designing Groupwork: Strategies for the Homogenous Classroom*, laid out a model to follow when designing group activities, to which the researcher ascribed. A group activity

- has more than one answer or more than one way to solve the problem
- is intrinsically interesting and rewarding
- allows different students to make contributions
- involves sight, sound, and touch; and
- is challenging. (p. 68)

When designing activities, the researcher made sure to follow these guidelines, as the goal of the group work was to give students the opportunity to synthesize and apply what they had learned via the video. Students were given instructions to use the manipulatives (generally pieces of paper that they could move around the table to match or line up) and then write them down in their notebooks. Students also used graphic organizers to synthesize complex processes. The practicality of graphic organizers helped students "depict relationships between facts…and assess understanding of new concepts" (Davidson & Worsham, 1992, p. 196). Thus, the classroom took on an active and intentioned learning environment, and students were never sitting passively at their task filling in notes or performing rote tasks. Students generally came to class with positive attitudes, and on more than occasion, asked to partake in specific activities they deemed as fun.

In the study conducted by Schultz et al. (2014) in a high school AP Chemistry class, the researchers listed three takeaways from the study: (1) Students in the flipped classroom were in charge of their learning, which led to an increase in student knowledge between the two groups; (2) students in the flipped classroom had more than one opportunity to learn the material, as they had access to the videos at any time; and (3) there was more time for teacher support in the classroom. The video lectures gave students the opportunity to pause or rewatch the lesson at their leisure. Instead of having the material presented only one time in class, students had a unique advantage over their peers in the control classroom. This advantage is articulated in a variety of studies, as students reported that one of the benefits of the flipped classroom was the ability to rewatch the lectures (Lape et al., 2014; Schultz et al., 2014). It is perhaps this articulated difference between the experimental and control groups that led to a numerical difference, although not significant, in the gain scores between each group.

Analyzing Subsets of Students

Though, again, none of the results of statistical analysis to determine differences in gender or achievement categories were significant, the raw scores still give insight into the effectiveness of the flipped classroom. An interesting result is that females experienced higher gain scores from pre-test to post-test between the control and experimental group, whereas males in the experimental group had lower gain scores than their male counterparts in the control group. Furthermore, while both males and females in the control group had the same percentage gain scores between tests (43%), there was a 17% gap between gain scores of males and females in the experimental group, with males gaining an average of 40% and females gaining an average of 57%. This phenomenon, albeit not significant, is an important difference to discuss. Surprisingly, these results are contrary to results obtained by Schultz et al. (2014) in their study of AP Chemistry students. In this study, the researchers concluded that males performed significantly better under the flipped classroom model than their male peers in the control classroom. However, Lage et al. (2000) reported that female perceptions of the flipped classroom were higher than male perceptions; females consistently reported greater satisfaction with the in-class activities. Additionally, the instructors that were part of this study “noted that women were clearly more active participants in class than in traditional classrooms (Lage et al., 2000, p. 37), a result that could be consistent with the higher gain scores in this study among females.

So, why do we see a difference between genders? Perhaps some of the difference can additionally be explained through an analysis of gender responses in regards to cooperative learning. In a book entitled *Women's Way of Knowing: The Development of Self, Voice and Mind*, the authors laid out five ways in which women view themselves when it comes to knowledge and relationships. One portion of their book deals with the idea of "connected knowers," in that women seek to understand each other and others' points of view as they gain knowledge (Belenky, Clinchy, Goldberger, & Tarule, 1986). Perhaps this idea can lead us toward an understanding of how women work in groups, specifically in the context of a cooperative learning classroom. Indeed, the researcher observed that female students in the experimental classroom seemed concerned about keeping their group on track and focused, and they were generally willing to listen to the views of their teammates. In one specific instance, the researcher observed a female expressing joy at understanding the concept and even remarking, "I understand it, and I love it!" The group environment, because it forced students of different ability levels and genders to work together and come to conclusions, allowed female students the opportunity to become "connected knowers," an idea which could explain the disparity in gain scores between males and females in the experimental classroom and a result not seen in the control classroom.

Additionally, in the discussion of the study conducted by Lage et al. (2000), the researchers remarked on the gender phenomenon that they observed in their own experiments. Drawing on research that shows that women prefer cooperative environments, Lage et al. (2000) made the conclusion that the inverted classroom gives "students the opportunity to relate experientially to the abstract concepts discussed in the textbook" (p. 41), a process that could positively impact female perceptions, and more broadly their academic gains, of and within the flipped classroom setting. Lage et al. (2000) cited a variety of studies that correlate with these conclusions and thus ultimately concluded that "a more inclusive environment, such as the inverted classroom, allows students who do not learn best in the traditional format to learn in alternative ways" (p. 41).

Another interesting way to look at the data collected was to divide students into subsets based on their ability level. By dividing the control and experimental classrooms into thirds, the researcher was able to perform statistical analysis in order to determine if there was significance in how the two groups, high-achieving and low-achieving, responded to the application of the flipped classroom. In both the control and experimental groups, the bottom third gained a higher percentage than the top third of the class, a result that was significant in both classes, with the experimental group having a slightly higher significance. While the gains in neither the top third nor bottom third between groups were significant, the raw gain score percentages showed that the experimental group saw greater increase in gain scores among both groups. It is interesting to note that analysis on the semester scores for both classes showed nonsignificant differences, meaning that both classes were relatively similar at the beginning of the intervention.

Regardless of treatment, analysis shows that the difference in gains between the top third and bottom third of students was significant, a result that is encouraging for a teacher but inconclusive for a researcher in terms of the effectiveness of the flipped classroom for certain groups of students. Overall, however, there may be a couple of reasons as to why the bottom third responded better to treatment than the top third. First, all students had exposure to content more than one time, as students were able to watch the video again if they did not understand the concept. For low-achieving students, the opportunity for repeated exposure is a significant advantage, because it gives them the opportunity to review concepts multiple times. Secondly, with the introduction of mixed-ability grouping in the experimental classroom, low-achieving students had the advantage of being pushed by high-achieving students. In their groups, these students could ask questions and work through problems with their peers who understood the concepts better. It students were grouped homogenously, low-achieving students might find themselves "stuck" and unable to make progress toward understanding. There is limited research on the effectiveness of the flipped classroom with regards to different achievement levels, so more research must be conducted in order to draw proper conclusions about achievement in specific relation to this treatment.

Conclusion

The melding of cooperative learning and technology has led to an interesting and novel idea known today as the flipped classroom. As technology integration within the classroom only increases, the technique of the flipped classroom can become a valuable tool for a world-class teacher. Though the research study outlined in this paper shows insignificant and inconclusive results on the effectiveness of the flipped classroom within a secondary mathematics classroom, the research and scholarship that ground this study should be taken seriously. Based on the analysis of results and the discussion of these findings, the researcher recommends a blended-learning class environment rather than a full classroom flip. In a blended-learning environment, the teacher incorporates the use of technology specifically and routinely, though not exclusively. From student responses and observations, in addition to ideas from other researchers (Schultz et al., 2014), a blended environment appeals to both types of learners: those who enjoy the traditional lecture-style classroom and those who enjoy the specific focus on outside learning and in-class cooperative activities. Additionally, a full classroom flip requires the construction of hundreds of videos, a task that is time-consuming and at times rushed and could lead to shallow online instruction that only reaches surface-level understanding instead of building conceptual depth. A blended approach gives equal footing to in-class teaching and online lectures, both of which can be higher quality.

In regards to additional research, more time should be dedicated to observing the specific impact a flipped classroom has on gender, as results in this study differ from limited results found in others. Do females respond better to the flipped classroom treatment? Ultimately, however, the results of this study show promise toward effective implementation of the flipped classroom, which can lead to greater student learning and understanding through active and collaborative learning. The flipped classroom is a promising technique that seeks to promote a learning environment that is active and engaging while also giving students opportunity to interact intellectually with their peers on a daily basis. This inversion of learning should thus be an integral part of the 21st-century classroom.

References

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

Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M. (1986). *Women's ways of knowing: The development of self, voice, and mind*. New York, NY: Basic Books.

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

Bonwell, C. C., & Eison, J. A. (1991). *Active learning: Creating excitement in the classroom* (ASHE-ERIC Higher Education Report No. 1). Washington, DC: George Washington University, School of Education and Human Development.

Bransford, J. D., Brown, A. L., Cocking, R. R., & National Research Council. (2000). *How people learn: Brain, mind, experience, and school* (Exp. ed.). Washington, DC: National Academy Press.

Chester, A., Buntine, A., Hammond, K., & Atkinson, L. (2011). Podcasting in education: Student attitudes, behaviour and self-efficacy. *Educational Technology & Society*, *14*(2), 236–247.

Cohen, E. G. (1994). *Designing groupwork: Strategies for the heterogeneous classroom* (2nd ed.). New York, NY: Teachers College Press.

Davidson, N., & Worsham, T. (Eds.). (1992). *Enhancing thinking through cooperative learning*. New York, NY: Teachers College Press.

Fulton, K. P. (2012, October). 10 reasons to flip. *Kappan*, *94*(2), 20–24.

Goodwin, M. W. (1999). Cooperative learning and social skills: What skills to teach and how to teach them. *Intervention in School and Clinic*, *35*(1), 29–33. http://dx.doi.org/10.1177/105345129903500105

Hawks, S. J. (2014). The flipped classroom: Now or never? *AANA Journal*, *82*(4), 264–269.

Hiebert, J., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. *Second Handbook of Research on Mathematics Teaching and Learning*, *1*, 371–404.

Jacot, M. T., Noren, J., & Burge, Z. L. (2014). The flipped classroom in training and development: Fad or the future? *Performance Improvement*, *53*(9), 23–28.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (1998). Cooperative learning returns to college: What evidence is there that it works? *Change: The Magazine of Higher Learner*, *30*(4), 26–35.

Kirvan, R., Rakes, C. R., & Zamora, R. (2015). Flipping an algebra classroom: Analyzing, modeling, and solving systems of linear equations. *Computers in the Schools*, *32*(3–4), 201–223. http://dx.doi.org/10.1080/07380569.2015.1093902

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

Lape, N. K., Levy, R., Yong, D. H., Haushalter, K. A., Eddy, R., & Hankel, N. (2014, June). *Probing the inverted classroom: A controlled study of teaching and learning outcomes in undergraduate engineering and mathematics*. Paper presented at 121st ASEE Annual Conference & Exposition, Indianapolis, IN.

Lumpkin, A., Achen, R. M., & Dodd, R. K. (2015). Student perceptions of active learning. *College Student Journal*, *49*(1), 121–132.

McManus, D. A. (2001). The two paradigms of education and the peer review of teaching. *NAGT Journal of Geoscience Education*, *49*(6), 423–434.

Millis, B. J. (2002). *Enhancing learning—and more!—through cooperative learning: Idea Paper No. 38*. Manhattan, KS: Kansas State University, The IDEA Center.

Moore, A. J., Gillett, M. R., & Steele, M. D. (2014, February). Fostering student engagement with the flip. *The National Council of Teachers of Mathematics*, *107*(6), 420–425.

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards*. Washington, DC: Authors.

Schultz, D., Duffield, S., Rasmussen, S. C., & Wageman, J. (2014). Effects of the flipped classroom model on student performance for advanced placement high school chemistry students. *Journal of Chemical Education*, *91*(9), 1334–1339.

Strayer, J. F. (2007). *The effects of the classroom flip on the learning environment: A comparison of learning activity in a traditional classroom and a flip classroom that used an intelligent tutoring system* (Unpublished doctoral dissertation). Ohio State University, Columbus, OH.

Strayer, J. F. (2012). How learning in an inverted classroom influences cooperation, innovation and task orientation. *Learning Environments Research*, *15*(2), 171–193. http://dx.doi.org/10.1007/s10984-012-9108-4

Topping, K. J., & Ehly, S. W. (Eds.). (1998). *Peer-assisted learning*. Mahwah, NJ: Lawrence Erlbaum Associates.

Appendix A

Survey

1. The videos were clear in the explanation of the material.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree
2. The in-class activities and group work helped me understand the material better.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree
3. I liked working with the same group of people every day.
    a. Strongly agree
    b. Agree
    c. Neutral
    d. Disagree
    e. Strongly disagree
4. If you explained "disagree" or "strongly disagree" to any of the above questions, please explain why.
5. Did you ever go back and re-watch the videos in order to prepare for a quiz or test?
    a. Yes
    b. No
6. What is something you liked about the flipped classroom? Be specific in your feedback.
7. What is something you disliked about the flipped classroom? Be specific in your feedback.