Effects of Flipping the Classroom on Learning Environment and Student Achievement

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Abstract

This action research project was carried out to determine if flipping the classroom has a positive effect on the learning environment. For nine weeks, I taped a video for each new lesson in my high school algebra 2 classes. Students were assigned to watch these videos as homework on their school-issued tablets in order to maximize time in class to complete problem sets. I aimed to investigate whether flipping the classroom increased student engagement, collaboration among peers, and interaction time with the students and teacher. To do so, I kept a teacher journal, administered a student survey, and held a focus group interview. I also examined how flipping the classroom affected student achievement; so I compared the experimental group to my previous year's algebra 2 students who received traditional in-class lectures. Common assessments were given to both groups and independent *t*-tests were used to evaluate academic achievement. Data analysis indicated collaboration with and amongst students increased, while overall academic performance did not change at a statistically significant level. Student engagement levels were not substantially higher while watching video lectures versus traditional in-class lectures, but students were noticeably more engaged during problem set completion time.

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Chapter One

Introduction

The classroom environment is ever-changing, and teachers must adapt in order to best meet student needs. During my first seven years of teaching I experienced the further integration of new technologies into the classroom, and a movement toward a national set of math standards, known as Common Core State Standards for Mathematics (CCSSM). Many teachers hoped CCSSM would provide solutions to the inch-deep and mile-wide content conundrum. In some respects, CCSSM are more focused than previous math standards. However, I found myself devoting additional instructional time to lecturing in order to cover these rigorous standards. As a result, I sacrificed question-and-answer time, as well as peer-to-peer collaboration opportunities.

The CCSSM has changed the learning environment and challenged me to do more with the same amount of classroom minutes. I struggled to cover every standard while still providing sufficient time for interactions with and amongst students. I also struggled to keep students engaged while devoting more time to direct instruction. The novel concept of the flipped classroom has recently been implemented by educators to address these very issues. In the flipped classroom, teachers record lecture material for students to watch outside of class. By video-recording part of classroom lectures, more class time should be available for activities and homework questions. Less class time is spent on delivery of new concepts, so students can instead actively engage in processing content and collaborating with peers. Demands of increased lecture time, as well as access to technology, have pointed educators toward the flipped classroom.

Motivation for the Project

Good teachers constantly reflect on teaching practices and look for ways to improve their delivery of content. During the 2013-2014 school year, sophomores, juniors, and seniors at the high school where I taught received electronic personal learning devices. These tablets extended the possibilities of classroom instruction. Therefore, the idea of flipping the classroom was a topic of discussion in my district. After six years of teaching, I wanted to update my instruction and keep students engaged. I had an interactive whiteboard in my room which provided me with a platform to record videos. All of the technology was in place, and flipping the classroom piqued my interest.

The past few years, I made a concerted effort to encourage collaboration in my classroom. I often had students share ideas or brainstorm with a partner. Higher order thinking requires students to formulate and deliver an explanation, and peers are often the best interpreters of a problem. The flipped classroom model seemed to provide students with opportunities to become more active participants in the learning process.

Background on the Problem

The mathematics classroom has undergone many changes in the past two decades, including increased accountability. Students are expected to meet rigorous mathematical standards to prepare for college. In the past few years, the CCSSM was developed as a way to move toward a set of unified national standards. At the high school level, implementation of these standards requires teachers to know and teach more challenging mathematics. In the fall of 2011, my school adopted textbooks that met the CCSSM. When this happened, my lectures increased approximately 10 minutes, or 20%, in each 50-minute class. As I attempted to cover all CCSSM concepts, I scrambled to interact with students and address their questions.

Access to technology also continues to transform education. When students at my school were issued electronic personal learning devices, my colleagues wondered how they could effectively incorporate this technology into the classroom. While some educators were familiar with video podcasts, the notion of the flipped classroom was relatively new. Limited research had been conducted on the flipped classroom, which does not simply involve linking lectures online. Personal learning devices presented an opportunity to incorporate technology into instruction through the flipped classroom model, while extending lecture time outside of the 50 minutes available in class. By providing access to lectures outside the classroom, more time should be available to address student questions, increase teacher and student interactions, and increase student engagement with mathematical content.

Statement of the Problem

Due to implementation of the CCSSM, more material needs to be taught. As a result, less time exists for student questions, interactions with students, and activities which encourage discussion and emphasize applications of mathematical concepts. In addition, students at the high school which I teach received personal learning devices this past year, which prompted some educators to consider the flipped classroom. By utilizing technology to deliver the lecture outside of class, more class time could be available for students to engage with the material while interacting with each other and the teacher.

Statement of Purpose

The purpose of this study was to investigate effects of the flipped classroom model on learning environment and student achievement. I collected data on in-class lecture time, interactions with and amongst students, student engagement, and overall grade trends for homework and assessments. Ultimately, utilizing technology should reduce class time traditionally spent on lectures. As a byproduct, I hoped the flipped classroom would provide students with more time to interact with each other and with me, thus increasing student engagement and achievement in my classroom.

Research Questions

The main research question was as follows: How does flipping the classroom change the learning environment? Related sub-questions included:

- Does flipping the classroom reduce lecture time in class, and as a result, allow for more interactions with and amongst students?
- Does flipping the classroom increase student engagement and achievement?

Definitions

Flipped classroom – According to Strayer (2012), the flipped classroom "uses technology to move lectures outside the classroom and uses learning activities to move practice with concepts inside the classroom" (p. 171).

Personal learning devices – "smart phones, iPod Touches, tablets, laptops, netbooks, or any other Internet enabled device" (Hegna, 2011, para. 1).

Video podcasts – audio or visual files which are distributed in digital format and can be downloaded from the internet or directly distributed to an audience (McGarr, 2009).

Summary

Teaching is a dynamic profession. Due to the rigor of CCSSM, topics once taught in fourth course advanced math classes are now being taught in first course algebra one classes. Increased pressure and accountability to cover these standards caused me to elongate classroom lecture time. Longer lectures potentially compromise student engagement levels and interaction time with and amongst students. As tablets are placed in the hands of students, new opportunities arise to change the learning environment. While flipping is a relatively new idea, it shows promise as a way to alleviate pressures associated with limited classroom minutes through tapping into the availability of technology. The flipped classroom could allow for more contact time with students, as well as increase opportunities for peer collaboration. This study aimed to analyze effects the flipped classroom has on learning environment and student achievement.

Chapter Two

Review of Literature

The flipped classroom recently developed in response to a variety of changes in the classroom environment, including learning preferences of students, limited classroom minutes, and increased access to technology. Thus, one flipped classroom may look different from the next. The following review of literature examines effects of flipping the classroom. Specifically, this chapter focuses on student and teacher collaboration, student engagement, student achievement, and reactions to flipping. This review serves as a guide for further study and implementation of the flipped classroom model.

The Flipped Classroom

The "flipped classroom" is a new catch phrase in education, but is not a completely novel idea. Teachers often assign reading to be done at home, and then expect students to engage in conversation about the reading in class. This design could be classified as an inverted classroom (Strayer, 2012). However, a few key characteristics distinguish the flipped classroom from an inverted classroom. In the flipped classroom, students watch video-recorded lectures outside of class, thus increasing time for active learning and practice to occur in class (Strayer, 2012). While implementation of this method may look slightly different for each teacher, essentially "the 'flipped' part of the flipped classroom means students watch or listen to lessons at home and do their 'homework' in class" (Fulton, 2012, p. 13).

Online learning has various definitions. Historically, video lectures were created to provide curriculum access to individuals who lived far from school. Teachers began realizing videos not only helped off-site students, but also students who were present during lectures (Cascaval, Fogler, Abrams, & Durham, 2008). Online classes gained popularity in the past decade, especially at the college level. However, students commonly complained about limited interaction and communication in purely online classes (Gecer & Dag, 2012). Flipping the classroom involves online learning through a series of video lectures, but is supported by face-to-face classroom discussions and individual help. Thus, the flipped classroom is different from traditional online learning environments.

Traditional classroom lectures often follow a one-pace-fits-all philosophy. Teachers may adjust their lectures based on student feedback, but some students will undoubtedly find the pace swift, while others find it slow. Video lectures provided through the flipped classroom model allow students to fast forward through examples they already understand, or pause and rewind to revisit topics which may require more processing time (Goodwin & Miller, 2013). Videos allow lectures to be broken into pieces, as opposed to traditional instruction which often contains a large volume of content delivered at one time (Brecht & Ogilby, 2008).

Salman Khan, a widely recognized online educator, popularized the flipped classroom through his website, Khan Academy. This website contains over 4,120 short educational videos, most detailing a specific math concept (Thomas, 2013). Khan works problems step by step on each video. "Khan's idea was that youngsters would watch the videos at home and work on problems in class, essentially 'flipping' the classroom" (Kronholz, 2012, p. 25). Students also frequent the website to get homework help when they are stuck on a problem. Khan seeks to change the way people think about education, noting "the old classroom model simply doesn't fit our changing needs" (Khan, 2012, p. 1).

Many schools have used Khan's videos to flip the classroom. Greg Green, principal at Clintondale Community Schools in Michigan, commended the flipped classroom for its ability to assist students who do not get homework help at home (Finkel, 2012). Students now receive guidance at home in the form of video lectures, and can directly interact with teachers and peers during class time to get answers to their questions. Teachers utilizing Khan Academy to flip their classrooms realize they often work harder during the school day as they are always moving around and interacting with students. It must be noted that Khan Academy is not meant as a fix-all. Math teacher Courtney Cadwell commented, Khan "is not great at helping kids conceptualize math" (Kronholz, 2012, p. 26). Video lectures need to be supplemented with activities which encourage discussion and emphasize applications of mathematics. When flipping the classroom, teachers must constantly interact with students, adjust instruction on the fly, and design activities which complement the videos.

Changing the Learning Environment

Collaboration. Technology allows for various learning environments and methods of instruction (Gecer & Dag, 2012). In recent years, differentiated instruction gained attention in education. Tomlinson (2005) pointed out differentiation should involve individual, small group, and whole class time. The flipped classroom allows for all of these recommended elements of instruction. In fact, Strayer (2012) found students receiving instruction in a flipped classroom environment were more willing to work together as compared to those receiving instruction in a traditional setting. Through interviews conducted during his research, Strayer noticed many students in the flipped classroom appreciated learning with a partner, whereas group learning was minimally mentioned as being correlated with success in traditional instructional settings. Herreid and Schiller (2013) observed a similar theme when examining case studies involving the flipped classroom model: "Active learning works best. Telling doesn't work very well. Doing is the secret" (p. 65).

A study involving 476 fourth and fifth grade Texan students found differentiated instruction was more prominent in classrooms utilizing computer instruction, versus control classrooms which relied primarily on teacher modeling. Half of the control classrooms made time for students to learn on their own, while this aspect was always present in the experimental classrooms using computers. Also, about twice as many one-on-one teacher and student conversations occurred in the experimental classrooms (Rosen & Beck-Hill, 2012). While large group instruction certainly has its benefits, the flipped classroom allows for this type of instruction to not dominate classroom minutes. Watching parts of lectures on the computer promotes active learning and provides opportunities to interact with students and differentiate instruction.

Learning in a small group setting is not always intuitive for students. In his experience with peer collaboration in the flipped classroom, Strayer (2007) observed students who shied away from group work. Some of his students began doubting themselves after arriving at a different answer than the rest of the group. Instead of discussing these differences with the group and using them as a learning experience, individuals began isolating themselves. It appeared some students would rather work alone with an incorrect answer than work with a group and discover the correct solution (Strayer, 2007). According to veteran math teacher Rob Warneke, "Kids need to be trained and guided to stay on task, work collaboratively, solve their own problems, be disciplined. This is harder than making everyone be quiet during a lecture" (Fulton, 2012, p. 14). Clearly, student collaboration can be a key component of the flipped classroom. However, collaboration may not be instinctive for all students. Teachers must foster positive collaboration within the classroom, and allow students time to become comfortable with this process.

Strayer (2007) reviewed multiple studies on learning styles associated with the flipped classroom in his dissertation. A 2004 study conducted by Broad, Matthews, and McDonald revealed when online learning was integrated into a college accounting course, students were more focused on the process of learning rather than the end result. “This suggests students have adjusted their approach to learning and as a result of the change in the learning environment” (Strayer, 2007, p. 66). Instead of concentrating on the answer, classroom discussion can shift to why a solution works, or the cognitive processes involved. Adjustments in learning styles may not happen overnight, but the flipped model allows for such active learning and classroom discussions.

Engagement. Audas and Willms (2001) defined student engagement as “the extent to which students participate in academic and non-academic school activities, and identify with and value schooling outcomes” (p. 12). Creating a learning environment which keeps all students engaged in the learning process constantly challenges teachers. This is especially difficult when a classroom contains learners with wide ranges of mathematical abilities. Teachers need to cover a large amount of material while holding high expectations for all students, including those who are not fundamentally sound (Brecht & Ogilby, 2008). If students are unable to comprehend classroom content, they may shut down. Similarly, students may disengage if material is delivered too slowly or is not stimulating. The flipped classroom aims to engage students from both ends of the spectrum. Struggling students can watch video lectures at their own pace, then receive additional support in class. Advanced students can skim through videos, then apply their knowledge to more difficult concepts and assist their peers. Video lectures can provide basic examples and review of background knowledge, thus allowing more time in class for higher level thinking and active learning (Brecht & Ogilby, 2008).

Today's students, who have always been surrounded by technology, learn differently than students from previous generations (Skiba & Barton, 2006). Students are accustomed to accessing information quickly and efficiently. Technology is an inherent part of their lives. According to Havana, Illinois Superintendent Mark Twomey (as cited in Finkel, 2012), "'All you have to do is watch kids in their free time. They always have some sort of electronic device in front of them'" (p. 30). The "Net Generation," or "Millennials," refers to people born in the 1990s and early 2000s (Howe & Strauss, 2000). "Net Generation characteristics include digital literacy, experiential and engaging learning, interactivity and collaboration, and immediacy and connectivity" (Skiba & Barton, 2006, para. 10). Students expect information to be at their fingertips and want to actively engage with technology and one another. Expecting students to take notes during a 30-40 minute mathematics lesson may not be the best platform for delivering instruction. Teachers must adapt to new learning styles to keep students engaged.

Technology can be used to engage students. Media-saturated students should find video lectures attractive (Brecht & Ogilby, 2008). In a study involving 136 middle school students from Ontario, 80% reported they liked watching video podcasts in class. Although 41% of students found the videos boring, 90% still thought they were better than using the textbook (Kay & Edwards, 2012). These findings are consistent with the learning preferences of the Net Generation.

The flipped classroom is in tune with attention spans of today's students. Research shows once someone's attention has been grabbed, there is only about a 10 minute window to keep it (Medina, 2008). In a study where 59 problem-based video podcasts were created to cover five units in a college pre-calculus course, researchers Kay and Kletskin (2012) analyzed data on video length. The mean video length was 7 minutes 40 seconds, with the longest video being 14 minutes 50 seconds. Each video included a problem the teacher explained, and a related problem the student had to solve. The mean time spent on the website was just under 6 minutes. Overall, 4,500 videos were watched by 195 students over a 3-week period, and 87% of the users found the videos to be useful. This study, paired with Medina's research, indicates optimal video length is around 10 minutes. The videos on Khan Academy also seem to support these findings, with Khan's average video length being about 10 minutes (Thomas, 2013). While this may not allow time for coverage of all concepts, it is important to create concise and focused videos.

Student Achievement and Perceptions

When properly implemented, schools using the flipped classroom model have observed increases in student achievement. In a survey of 453 teachers who flipped their classrooms, 67% noted an improvement in test scores (Goodwin & Miller, 2013). When Clintondale Community Schools in Michigan flipped their math classrooms, freshmen math failures dropped from 44% to 13% in just one year (Finkel, 2012). Data from the Byron School District in Rochester, Minnesota showed flipping the classroom increased student achievement by a notable amount. The number of students scoring 80% or above on calculus tests rose by nearly 10%, while pre-calculus showed an average increase of 6.1%. Similar results were observed in Byron's algebra and geometry courses (Fulton, 2012).

Documented successes can perhaps be attributed to increased student and teacher contact time. Providing more time for teachers to interact with students, versus standing in front of the classroom and delivering content, is one goal of the flipped classroom. This contact gives teachers more opportunities to provide students with feedback (Goodwin & Miller, 2013). Feedback allows students to immediately learn from their mistakes. Students can receive feedback not only from the teacher, but through collaboration with one another. As a result of classroom collaboration, the teacher in turn receives feedback from students. Such feedback can be used by teachers as a formative assessment, which is necessary to direct instructional plans (Tomlinson, 2005).

Educational studies have been conducted to investigate the importance of feedback in the classroom. A meta-analysis involving 717 students across multiple grade-levels and subjects found feedback had an effect size of 0.76 (Beesley & Apthorp, 2010). The closer an effect size is to 1.0, the more significant the result. When reviewing Beesley and Apthorp's study, Goodwin and Miller (2013) noted, "Feedback has one of the strongest effect sizes of any instructional practice" (p. 79). Specific opportunities provided in class for students to practice concepts with corrective feedback was found to be almost four times as effective as homework the students completed without guidance (Beesley & Apthorp, 2010). Increased opportunities to provide feedback is one of the attractive features of the flipped classroom.

Each flipped classroom is unique; thus, reactions to flipping are not all positive. Many students have difficulty making connections between online lectures and classroom instruction and activities (Strayer, 2012). Teachers must put in extra effort to ensure the two pieces align. Finkel (2012) noted students prefer videos made by their teachers, as these videos are customized to fit the curriculum. Fulton (2012) confirmed most students prefer watching videos made by their teacher, although she noted some students gain new perspectives by watching a different teacher's video from the same school. Pre-made videos from the internet or book resources are convenient, but results may be less favorable.

The flipped classroom presents other obstacles. A limiting aspect of the flipped classroom is internet access (Gecer & Dag, 2012). Educational institutions wishing to promote the flipped classroom must ensure all stakeholders have access to appropriate technology. Also, according to Clark and Mayer (as cited in Kay & Kletskin, 2012), the ability to pause videos, rewind them, and watch them multiple times benefits many learners, but advanced students often find the videos tedious and too basic. Using videos to change the learning environment does not eliminate concerns involving the engagement of all students.

Research shows the flipped classroom does not always positively influence the learning environment. Strayer (2007) conducted research involving two classroom models for delivering instruction in his college level statistics course. One class followed the traditional method of instruction; while his other class was flipped. Students in the flipped classroom watched video lectures from a tutoring system outside of class and did more projects and homework in the classroom. Strayer found students who received instruction through the flipped style were "less satisfied with how the structure of the classroom oriented them to the learning tasks in the course" (p. 4). Students in the flipped classroom seemed less comfortable with the style of learning, possibly because they were responsible for taking charge of the learning process. Their feelings could also be contributed to the fact Strayer, the instructor, did not make the videos for his students. Additionally, Strayer pointed out students need time to adjust to a radically different method of instruction.

Research reviewed in Strayer's (2007) dissertation indicates participants in other studies preferred the flipped classroom. Students "felt they received more personal attention due to the structure of the class, had more control over their learning, and were able to engage in critical thinking that explored the implications of their learning" (Strayer, 2007, p. 62). Through his research, Strayer found collaboration and participation were more present in flipped versus traditional classrooms. Decreased stress was reported among students watching the video lectures. A different study reviewed by Strayer found delivering content through traditional methods versus video lectures did not cause significant differences in pre-test and post-test results. While significant differences in student achievement were not evidenced by his research, the main distinction was an increased preference for collaboration among students in the flipped classroom (Strayer, 2007).

Research on the flipped classroom is new, but other studies have also shown no significant difference in student achievement. Finkel (2012) reported fifth-grade math teachers in Stillwater, Minnesota found flipping their classrooms had no effect on test scores, but did allow them to move at a faster pace. On average, the teachers covered two more weeks of material than in previous years. Teachers felt more freedom to differentiate instruction, and in turn, students developed a more positive outlook on math. Although scores did not rise, flipping produced other benefits.

Student commitment to watching video lectures outside of class affects the level of success experienced in the flipped classroom. Those who choose not to watch videos are unprepared for in-class activities, as they have not reviewed the content. Many teachers who tried the flipped method gave a short quiz or assigned homework that covered information in the video (Herreid & Schiller, 2013). Such activities increase student accountability to complete the "homework." Success levels may also be attributed to the quality of videos presented to students, as well as instructional preparation. Teachers must thoughtfully prepare for additional class time due to decreased lecture time. Clearly many variables are involved, and different implementations of the flipped classroom produce varying results.

Summary

Today's students have different learning preferences than students from previous generations, and teachers must adapt their instruction accordingly. Access to technology is more prevalent than ever before, and the flipped classroom taps into this resource. Assigning video lectures as homework can free-up class time, which in turn provides increased opportunities for teacher feedback and student collaboration.

The flipped classroom model addresses many learning styles of today's students. The computer becomes an instructional medium; lessons are broken into manageable chunks; videos can be accessed at any time; and more chances are created for interactions with and amongst students. Research on the flipped classroom is relatively new, and its success appears to depend on its implementation. No single formula is infallible, but the flipped classroom shows promise as a way to meet the changing needs of students.

Chapter Three

Research Design and Methods

There are different ways to flip the classroom. In this chapter, my classroom setting and procedures for flipping are described. Also, data collection methods used during the research process to analyze changes in the learning environment and student achievement are outlined. Timelines for implementation and expected results are included.

Setting

This study was carried out during my seventh year of teaching. All seven years were spent at a large high school in North Dakota. This particular year, I taught three geometry classes and two algebra 2 classes. I chose to only flip my algebra 2 classes as I had no prior experience recording video lectures. Recording can be time consuming, and I wanted to create quality videos.

I conducted research in my algebra 2 classes instead of my geometry classes for a variety of reasons. First, the mean age of my algebra 2 students was higher. Although they contained a few freshmen, my algebra 2 classes were primarily comprised of sophomores and juniors and a handful of seniors. Algebra 2 students typically complete more homework than younger geometry students. Second, about half of my geometry students had tablets issued by the school district that year, whereas all of my algebra 2 students received them. Last, the algebra 2 chapters I flipped seem conducive to learning through video lectures. Some geometry chapters, such as those which rely heavily on proofs, were not as intuitive for me to flip.

I flipped both of my algebra 2 classes to create a larger sample. In the two classes, 41 students participated in the study, 3 of whom were not in my class first semester. When comparing academic changes, only the 38 students who were in my class all year were included in the data analysis. The control group was comprised of 39 students from my previous year's two algebra 2 classes. Therefore, I minimized any significant curriculum changes, including lecture and assessment materials. I also attempted to maintain the prior year's pacing. The previous year, I had 22 students in my algebra 2 classes both semesters who were freshmen or sophomores, which would classify them as advanced students. I also had 17 juniors or seniors. Out of the 38 students who were in my algebra 2 classes both semesters during the year I conducted research, 20 were freshmen or sophomores and 18 were juniors or seniors. Thus, the ages of the students in the control and experimental groups were comparable.

Intervention/Innovation

For nine weeks, I flipped my classroom. Student attention spans must be considered when creating video lectures, yet all of the content must be covered. Therefore, I limited video lengths to 10-20 minutes. I created a routine for my flipped classroom so students got in the habit of watching videos. Students were assigned to watch a video outside of class before each new lesson. Videos were uploaded online at least 24 hours prior to class. Once students arrived in class, they immediately picked up the problem set. Problem sets are daily problems I give my algebra 2 students to help them practice material presented during lectures. They are often worksheets I have pieced together, but occasionally are questions from a math textbook. I assign problem sets, traditionally referred to as homework, with each new lesson. Students were encouraged to work with one another on problem sets, and I used this time to address individual questions. I also encouraged students to take notes while watching the videos, and often directed students to their notes when they had a question. If they were unable to produce notes, I suggested they revisit the video.

When students picked up problem sets at the beginning of class, I wrote a handful of those questions on the board. On a typical day in the flipped classroom, I might say, "Be prepared to share your answers for #3, 5, 10, and 14." As a form of accountability, I selected students to work out solutions to these problems on the whiteboard. Most of the time I used my graphing calculator to randomly select students, while occasionally I just asked for volunteers. These students were selected about halfway into the 50-minute classroom period to come to the whiteboard. After they shared their work, I brought the class together as a large group and we discussed each problem, addressing questions as we went. This was a way to highlight important concepts in the lesson. Often there were not very many additional questions asked during this time, but it was a good checkpoint for many students. After these 5- to 10-minute discussions, students kept working collaboratively or individually on the rest of the problem set. If students finished the problem set in class, they were prompted to start watching the video for the next day.

My seating chart was designed for students to sit next to a partner. All year I encouraged each pair to share ideas when problem solving. To promote collaboration on problem sets during the flipped classroom intervention, I let students choose their seats. I urged students to sit next to someone who would make them better, not someone who would be distracting.

Design

Both qualitative and quantitative data were collected to address my research questions. To better understand effects flipping had on the learning environment, a survey was administered. This quantitative measure provided feedback on engagement in class, collaboration opportunities, and overall perception of learning through the flipped classroom. Qualitatively, I kept a journal to gather data on these same elements. As students may not elaborate on a survey, and I cannot observe everything as a teacher, I attempted to triangulate data gathered on the learning environment by conducting student interviews. Interviewing a group of students provided additional insight into student opinions. When analyzing the qualitative data, I used inductive analysis to identify common themes in student responses and my journal entries.

Additional quantitative measures were used to gather data. Throughout the year I tracked how classroom minutes were spent. I also tracked my algebra 2 students' completion of problem sets, as completion rates can be tied to success on quizzes and tests. To investigate student achievement, I compared quiz and test scores of last year's algebra 2 students to this year's analogous scores using a *t*-test of independent samples.

Description of Methods and Analysis Strategy

Before beginning my research, I received approval from the principal at my high school (see Appendix A) as well as the associate superintendent of teaching and learning for the district (see Appendix B). I also received approval (see Appendix C) from Minot State University's Institutional Review Board (IRB). Consent forms (see Appendix D) were sent home with my algebra 2 students for their parents or guardians to sign prior to starting the study. Students were also given an assent form (see Appendix E). These forms outlined data collection techniques and my procedure for flipping the classroom, assured student confidentiality, and gained consent.

During the flipped classroom intervention, I kept a detailed journal of my observations in class. I recorded events I witnessed in the classroom as well as my perceptions about student achievement, engagement, and collaboration. After the nine weeks, I reviewed my journal and summarized my observations, citing evidence that supported commonly appearing themes. Throughout the school year, I documented the usage of classroom minutes on days when new material was administered in algebra 2. I recorded approximately how many minutes I spent lecturing and answering questions over previous material, and how many minutes students had to work on problem sets (see Appendix F for an example) to determine how classroom time was spent. Mean problem set completion rates for the experimental group were tracked to reveal any trends from semester one to quarter three. Problem sets were not collected daily, but rather on quiz days which occurred about once per week.

To assess student achievement, I used mean percentages for quizzes (see Appendix G for an example) and tests (see Appendix H for an example) to compare students participating in the study (experimental group) to my previous year's algebra 2 students (control group). First, I conducted a *t*-test of independent samples using first semester data to determine whether the two groups of students, control and experimental, were academically comparable. I used four quizzes and two tests which were extremely similar if not identical to the previous year's assessments. I also compared students' most recent Measure of Academic Progress (MAP) mathematics test scores, which is a computer-based standardized test given to students in third through tenth grade. The difficulty of this test adjusts based on student responses, and scores reveal overall understanding of mathematics content, regardless of grade level (Northwest Evaluation Association, 2013). A colleague took data from the control group's assessments, reordered it, and deleted student names to remove all identifiers. The null hypothesis was no difference in mean achievement scores of the control and experimental groups; the alternative hypothesis was a difference in the means of the two groups. When analyzing results, I used a 0.05 significance level. If the *p*-values of selected assessments were greater than 0.05, I concluded the academic performance of the control and experimental groups were not statistically different.

During the flipped classroom intervention, quiz and test grades were recorded. These assessments covered nearly identical material to my previous year's algebra 2 assessments. Independent *t*-tests were again run using intervention period data to determine whether the students in the flipped classroom had significantly higher quiz or test scores than the control group. During the intervention, four quizzes, two tests, and one mini test were given. Results of these *t*-tests can be found in Chapter Four.

After nine weeks of flipping the classroom, a student survey (see Appendix I) was administered in class. This survey contained 18 statements scored on a five-point Likert scale, and two free response questions. For each statement, students indicated whether they strongly disagreed, disagreed, had no opinion or were neutral, agreed, or strongly agreed. Two free response questions at the end of the survey addressed positive and negative feelings associated with the flipped classroom. Students were given at least 15 minutes to complete the survey. Survey items were designed to address the research questions involving student engagement and collaboration opportunities. Additional questions were asked to gain insight into students' perception of learning and academic achievement while the classroom was flipped. A few questions also addressed how students watched the videos. When reviewing survey results, I took special note of items in which data were skewed in one direction. For the free response questions, I recorded the frequency of common themes.

Ten questions with similar themes were also created for a group interview (see Appendix J). The interview process was semi-structured in format, as some of the questions had optional sub-questions (Mertler, 2012, p. 124). Five students gathered in a classroom as we had a similar free period. I chose students from varying abilities and engagement levels as well as both genders and different ages to get an honest representation of student opinions. When analyzing interview questions, I again identified common themes in responses.

By collecting qualitative and quantitative data through a variety of means, I attempted to triangulate data results. Although each method for gathering data was different, triangulation allowed me to be more confident with my results. Analysis of data collected along with interpretation of results is found in Chapter Four.

Expected Results

Before conducting my research, I hypothesized flipping the classroom would cause lecture time in class to decrease. I predicted students would be more engaged with problem sets due to increased work time. I strongly believed students would appreciate opportunities to collaborate with peers and ask me questions. These were themes I anticipated emerging from my journal notes, student surveys, and student interviews. Ultimately, I expected problem set completion scores to rise in the flipped classroom. As a result, I anticipated quiz and test scores might also rise slightly compared to the previous year, but did not expect them to increase at a statistically significant level. I realized it would be difficult to credit any positive results to one aspect of the flipped classroom as they could be attributed to video lectures, increased problem set completion rates, collaboration opportunities, the content being studied, or other unknown reasons.

While I imagined students would appreciate more class time to complete problem sets, I anticipated mixed feelings toward learning through video lectures. Just as some students prefer a physical textbook over an electronic textbook, some students may prefer face-to-face learning over video lectures. I was certain not all students would watch every video every day; thus, was prepared to direct students to the video during class if needed. I did expect student engagement levels during class to increase due to reduced lecture time.

Timeline for the Study

The study itself took nine weeks. During those nine weeks I created 25 videos, one for each lesson. Each day, I recorded my observations in my teacher journal. Data from quizzes and tests were compiled, and classroom surveys were completed shortly after the study was finished. Student interviews were conducted the week following the study's completion. All of these data were analyzed, and results of the study were written.

Summary

For nine weeks, I flipped my algebra 2 classes. During this time, students were assigned to watch short videos covering lecture material on their school-issued tablets as homework. One purpose of flipping was to allow more time for me to interact with students as they worked on problem sets, and for students to help each other. I hypothesized this change would positively influence student engagement and collaboration levels, possibly increasing student achievement. To measure the effectiveness of the flipped classroom, data were collected through a variety of qualitative and quantitative measures including student surveys, student interviews, teacher journals, a classroom minutes log, and assessment grades. Chapter Four contains results of the data collection process as well as an interpretation of those results.

Chapter Four

Results and Interpretations

I flipped my algebra 2 classes with the intent of positively changing the learning environment. Through journaling, a student survey, a focus group interview, and common assessments, I gathered data to examine effects flipping had on collaboration levels, student engagement, and student learning and achievement. This chapter contains analysis of these data, along with interpretation of the results.

Results of Data Analysis

Journal. Qualitative data were collected through a teacher journal which was updated daily, with the exception of summative assessment days. Analysis of these qualitative data aimed to address whether flipping the classroom decreased classroom lecture time, thus allowing more time for students to collaborate and engage with mathematical content. At the end of the flipped classroom intervention, 31 journal entries had been recorded.

Initially when I introduced the concept of the flipped classroom, I was met with much resistance. One student commented, “Why fix it if it’s not broken?” After explaining each flipped classroom was different and stating my reasons for flipping, most students seemed willing to give the videos a try. I then gave students half an hour to watch the first video in class, and at the conclusion students were generally positive. Three girls even stopped me after the first class to tell me they liked the video. Some students wanted to start on the problem set, but I told them they would have to wait until the next day’s class.

During the flipped classroom, I was extremely pleased with effort students put forth to complete problems sets. I was also pleased with students’ willingness to collaborate with one another. I let students choose their seats, as to encourage discussion. On the second day of flipping, a student had his hand raised. As I was on my way over, the student sitting behind him said, "Oh I can help you with that one. I'm good at those." A similar conversation was overheard on day 10: "Okay, I don't know how to do this one." The student's shoulder partner replied by saying, "Okay, I'll show you." During the first chapter review in the flipped classroom, I noticed increased independence as compared to the traditional classroom. While students regularly asked me questions, the majority of discussions occurred between peers. From my observations, 30 students regularly engaged in discussion with their peers, while the other 11 worked more individually.

By the end of the nine-week intervention, the majority of students first consulted a neighbor if they had a question, instead of initially seeking me out. I would regularly hear dialogue such as, "What did you get for number 27?" or "Were you just talking about number 25?" Only on one occasion did I sense a student was frustrated when helping a peer. Sometimes I reminded myself not to intervene when peers were having a conversation, as valuable learning was taking place. One such instance occurred when student partners were discussing domain restrictions. One student set-up an equation and solved, arriving at $x^2 \neq \frac{-3}{2}$. A discussion then ensued about how no real number squared produces a negative number. The second student realized this meant there were no restrictions; so the domain was all real numbers. On another occasion, two groups of students were comparing different methods to solving the same problem. One group had an interesting approach I had not considered. I stood in close proximity and enjoyed observing the discussion. During the last chapter, one student sought the help of another student across the room, even though I was standing close by. I was not used to such independence. These were positive signs that students felt comfortable asking each other questions and were engaged in the learning process.

I most commonly answered questions when students were in disagreement with one another, or if a peer's explanation was unclear. I also regularly touched base with students who were primarily working independently, and those who struggled with a particular concept. Answer keys to each problem set were posted in the room. Students often checked these to see if they were on the right track. Even after a few weeks of flipping, I was not used to students having so much time to ask me questions. By increasing my contact with individual students, it became more obvious to me when the class struggled with a particular concept. Being accessible to each student in class on a daily basis was a major benefit of the flipped classroom.

My journal continually contained entries involving student engagement. Before class I placed the problem set on a table in front of my classroom, and would often stand in the hallway to greet students as they entered. On multiple occasions I peered into the classroom and observed almost everyone working on the problem set. The bell had not even rung! Increased engagement was especially apparent in students who did not spend much time doing homework in the traditional setting. One such student said, "I liked the flipped classroom because then I do my homework." Another said, "We should do this in all our classes." Conversely, a student who always completed homework noted, "I get sick of watching videos at home." My students who did not consistently complete homework in the traditional setting seemed to be the most outspoken about keeping the flipped classroom.

Engagement was apparent on many other occasions as well. Students who did not normally contribute during large group lectures were regularly engaged in conversations with their peers. Similarly, students who did not ask questions in front of the entire class spoke up in the flipped classroom environment. Such students seemed comfortable asking me or their peers questions on an individual basis. Also, I frequently observed students thinking through problems instead of just regurgitating information. One such case occurred during a lesson on solving exponential equations. Instead of solving $2^x = 12$ by taking the log of each side of the equation, about one quarter of students in my first class immediately rewrote the equation as $\log_2 12 = x$. This was interesting as it was not a method I addressed in the video, but was intuitive to a handful of students.

Halfway into class almost every day I randomly selected about five students to write their answers to a problem set question on the whiteboard. One student was quite reluctant to share his answer the first time he was called upon. It took some convincing and me checking his answer before he agreed. By the end of the flipped classroom intervention, he walked right up to the whiteboard when his name was called. Other students seemed eager to share their work. This was a way to keep students accountable, get everyone involved, and give students a chance to check their progress.

After flipping the classroom third quarter, I went back to the traditional style to teach a chapter on trigonometry. It was quite apparent to me during the whole class lectures that a handful of students were noticeably disengaged. One student who was a great teacher during the flipped classroom now had his head down during the notes. It seemed the pace of the traditional classroom was too slow for him. Also, classroom discipline seemed slightly more difficult, as students were used to talking with each other all the time in the flipped classroom. During the traditional classroom lectures, I gave students opportunities to attempt problems and consult with a neighbor, but much of the time I expected them to be quiet. Early on in my flipped classroom journal I wrote, “Sometimes I miss having control.” When I went back to traditional lectures, the learning environment was less interesting. I realized I needed to give up some control to increase engagement. Two weeks after ending the flipped classroom, I started brainstorming ways I could increase engagement in a lecture-based classroom. I also looked for upcoming chapters that would work well with video lectures.

While the majority of my flipped classroom journal contained positive entries, the most frequently occurring negative theme related to students not watching the videos. One week into the study, I noticed more students were relying on their neighbor to not only address confusion, but to completely explain a concept. After two weeks, I estimated about 25% of students were not watching the video lectures before class. After five weeks, I again observed about the same percent of students were unprepared for class. This became especially apparent during lessons containing concepts students had no prior knowledge of, such as composite function notation and properties of logarithms. On occasion, students would say they watched the video and didn't get it, but could not produce any notes. This made me skeptical that quality time was spent watching the video. Daily, students admitted to me they did not watch the video, and asked for permission to watch in the hallway or plugged their headphones into their tablet and watched in class. These students often got behind on the homework, and missed out on collaboration opportunities.

Upon noticing an increase in the number of students who had not watched the assigned video lectures before class, I began to compile data. I went to my YouTube channel and recorded the number of views for each video right before school started for that day's lesson, right before class, right after class, and at the end of each chapter. This way I got a better idea of how many people were watching the video at home, how many were watching it in the morning at school, and how many people were accessing it during class. On occasion I forgot to collect these data, but I did gather it for 14 of the 21 videos students were assigned to watch for homework. I did not collect data from the 6.0a, 6.2b, 6.6a, and 6.8 videos as I allotted class time for students to watch those videos. Frequencies are in Table 1 and the video views statistics are in Table 2. Note, the number of views reflects any time a video was opened; so 40 views does not necessarily mean 40 different students watched the video. Forty-one students between my two algebra 2 classes were expected to watch each video. Note the mean number of views before class was 31, which is consistent with my journal observations of approximately 25% of students not watching the videos.

Table 1

Number of Video Views at Given Times

Lesson	Start of School	Before Class	After Class	End of Chapter
6.4a	27	36	43	62
6.4b	32	38	39	58
6.5a	24	29	38	62
6.5b	27	33	43	61
6.6b	27	33	49	64
6.7a	28	39	49	78
7.1a	36	---	49	79
7.1b	39	50	68	82
7.2	21	29	36	50
7.3a	17	23	39	50
7.3b	29	32	39	64
7.3c	20	24	30	50
7.5	17	20	23	42
7.6	12	17	28	51

Table 2

Measures of Central Tendency of Number of Video Views

Given Time	*N*	*M*	*Mdn*	*Min*	*Max*
Start of School	14	25.4	27.0	12	39
Before Class	13	31.0	32.0	17	50
After Class	14	40.9	39.0	23	68
End of Chapter	14	60.9	61.5	42	82

During the flipped classroom intervention, mean problem set completion rates increased by about 6%. This seemed to be an obvious result of providing class time to work on problem sets. On average, students had 36 more minutes of class time to work on problem sets during the flipped classroom intervention as opposed to the traditional classroom setting. However, incomplete assignments were still turned in. Many students who turned in incomplete problem sets were the same students who were not regularly watching the videos. Absences also caused some students to get behind. Even though absences are a problem in the traditional classroom, it especially hurt the flipped classroom as student collaboration was a major component of the learning environment. Nevertheless, a few students noted it was easier to catch up after being gone when videos were available. One student commented, “The thing about the videos is if you miss, it’s really easy to make-up.” Problem set completion rates before and during the intervention can be found in Table 3. Classroom minutes devoted to lecture can be found in Table 4, and classroom minutes devoted to problem set completion can be found in Table 5.

Table 3

Problem Set Completion Percentages for Experimental Classes

Problem Set Completion Percentages	*N*	*M*	*SD*	*Mdn*	*Min*	*Max*
Traditional Classroom	38	85.413%	19.008	93.2%	23.9%	100%
Flipped Classroom	38	91.837%	14.207	97.4%	23.2%	100%

Table 4

Classroom Minutes Devoted to Lecture when Teaching a New Concept

Lecture Minutes	*N*	*M*	*SD*	*Mdn*	*Min*	*Max*
Traditional Classroom	35	40.914	5.226	41	30	50
Flipped Classroom	21	4.857	6.069	5	0	26

Table 5

Classroom Minutes Devoted to Problem Set Completion when Teaching a New Concept

Problem Set Completion Minutes	*N*	*M*	*SD*	*Mdn*	*Min*	*Max*
Traditional Classroom	35	9.086	5.226	9	0	20
Flipped Classroom	21	45.143	6.069	45	24	50

Survey. A 20-item survey (see Appendix I) was administered to students at the completion of the flipped classroom intervention period. For the first eighteen statements, students indicated whether they strongly disagreed, disagreed, had no opinion or were neutral, agreed, or strongly agreed. These responses were analyzed to gain insight on collaboration opportunities, engagement, and overall perceptions of learning and academic achievement during the flipped classroom intervention. Also, a few statements specifically addressed watching the videos. Tables 6-9 show the percent of students who marked each response rounded to the nearest tenth of a percent, categorized by collaboration opportunities, student engagement, perceptions of learning and academic achievement, and approaches to watching video lectures. For items 1-10 and 15-18, the “agree” and “strongly agree” choices indicate positive student perceptions toward collaboration, engagement, or the learning environment during the flipped classroom intervention. Negative student perceptions toward these elements are reflected in the “disagree” and “strongly disagree” choices. The “neutral” choice indicates no preference or no perceived change. Items 1-10 and 15-18 can be found in Tables 6-8. Items 11-14, included in Table 9, addressed characteristics specific to how videos were watched. These four items were not related to the research questions, but included in the survey because they provided useful information.

The greatest volume of positive student perceptions occurred for the survey items related to collaboration, as seen in Table 6. For all three of these survey items, more than 75% of students marked “agree” or “strongly agree.” Of the students surveyed, 90.3% thought the flipped classroom allowed more time to ask the teacher questions in class, 90.3% spent more time working with classmates, and 82.9% felt they understood the problem sets better when working with a classmate. Only one student experienced negative effects with regards to understanding material when working with peers.

Table 6

Student Responses to Survey Items Related to Collaboration

Item	SD	D	N	A	SA
4. When the classroom was flipped, I spent more time working with classmates.	0.0%	0.0%	9.8%	36.6%	53.7%
5. I understand the problem sets (worksheets) better when I work with a classmate.	0.0%	2.4%	14.6%	36.6%	46.3%
6. The flipped classroom allowed for more time to ask the teacher questions in class.	2.4%	0.0%	7.3%	22.0%	68.3%

Three of the four survey items related to student engagement also indicated strong positive student perceptions, as seen in Table 7. Items 16 and 17 involved taking notes during the videos and the ability to focus better when the lecture was broken into smaller parts. For both of these items, 73.2% of students indicated they “agreed” or “strongly agreed”. Item 15 revealed 80.5% of students paid better attention to videos when they were made by a teacher versus using videos from another source. However, item 9 suggests only 46.3% of students were more engaged watching videos than they were during in-class lectures. Disregarding the items related to video watching, item 9 received the largest percent of “disagree” or “strongly disagree” responses, with 29.2% of students reporting they did not feel more engaged during the videos.

Table 7

Student Responses to Survey Items Related to Student Engagement

Item	SD	D	N	A	SA
9. I was more engaged watching the videos than I was during in-class lectures.	14.6%	14.6%	24.4%	34.1%	12.2%
15. I pay better attention to the videos when they are made by my teacher versus using pre-made videos from another source.	0.0%	0.0%	19.5%	39.0%	41.5%
16. When I watched the videos, I took notes.	14.6%	2.4%	9.8%	19.5%	53.7%
17. I am able to focus better when the lecture is broken into smaller parts.	2.4%	2.4%	22.0%	41.5%	31.7%

Table 8 displays the survey items related to student learning and academic achievement. The statements in this category with the strongest student perceptions were items 1 and 7. Of the students surveyed, 87.5% “agreed” or “strongly agreed” that the video lectures helped them understand math concepts. Even though item 9 indicates these students were not necessarily more engaged during video lectures than they were during in-class lectures, learning was taking place through the videos. For item 7, 100% of students indicated the flipped classroom allowed more time to complete problem sets in class. These results echo the data displayed in Tables 4 and 5.

Three additional items in Table 8 showed slightly lower positive student perceptions, with 50-75% of students indicating they “agreed” or “strongly agreed.” Item 2 revealed 68.3% of students would rather watch a video lecture for homework than do math problems for homework, while item 3 indicated 53.7% of students preferred the flipped classroom over the traditional classroom format. Item 18 indicated 61% of students wanted to continue learning math through the flipped classroom format, while 19.5% had no preference.

The remaining two survey items in Table 8 indicated moderately positive perceptions. On items 8 and 10, 30-50% of students indicated they “agreed” or “strongly agreed.” Item 8 showed nearly half of the students surveyed felt they understood problem sets better when the classroom was flipped, but item 10 indicated only 34.1% learned better through the videos versus in-class lectures. The discrepancy in these data points toward the importance of collaboration in the flipped classroom. Even though 65.8% of students did not think they learned better through the videos, 48.8% still believed they understood the problem sets better when the classroom was flipped. Items 8 and 10 also received the largest percent of neutral responses, with 41.5% and 43.9%, respectively.

Table 8

Student Responses to Survey Items Related to Student Learning and Academic Achievement

Item	SD	D	N	A	SA
1. The video lectures helped me understand math concepts.	5.0%	0.0%	7.5%	75.0%	12.5%
2. I would rather watch a video lecture for homework than do math problems for homework.	7.3%	9.8%	14.6%	22.0%	46.3%
3. I prefer the flipped classroom over the traditional classroom format.	7.3%	12.2%	26.8%	31.7%	22.0%
7. The flipped classroom allowed more time to complete problem sets (worksheets) in class.	0.0%	0.0%	0.0%	24.4%	75.6%
8. When the classroom was flipped, I understood the problem sets (worksheets) better.	4.9%	4.9%	41.5%	31.7%	17.1%
10. I learned better through the videos than I did through in-class lectures.	7.3%	14.6%	43.9%	31.7%	2.4%
18. I want to continue learning math in the flipped classroom format.	7.3%	12.2%	19.5%	36.6%	24.4%

Table 9 contains items 11-14, which directly related to how students watched video lectures. On item 11, 53.7% of students indicated they watched video lectures prior to class, while 7.3% indicated they did not and 39% were neutral. Assuming those students marking “neutral” sometimes watched video lectures prior to class and sometimes did not, these responses were consistent with my journal observations of about 25% of students not watching video lectures prior to class. Nearly 66% of students paused the videos to process content, and 58.6% rewound some videos or watched them more than once. Almost 44% of students fast forwarded some videos. Responses to items 12, 13, and 14 relate to pace of learning. While a teacher can pause and provide processing time during traditional classroom lectures, video lectures allow each student to control the learning pace. It appears the majority of students took advantage of this opportunity.

Table 9

Student Responses to Survey Items Related to Watching the Videos

Item	SD	D	N	A	SA
11. I watched the video lectures prior to class.	4.9%	2.4%	39.0%	29.3%	24.4%
12. I often paused the videos when watching them in order to process the content.	7.3%	12.2%	14.6%	53.7%	12.2%
13. I rewound some videos or watched them more than once.	17.1%	19.5%	4.9%	41.5%	17.1%
14. I fast forwarded the videos when watching them.	14.6%	22.0%	19.5%	36.6%	7.3%

In order to analyze measures of central tendency of student survey data, a numeric value was assigned to each response type: strongly disagree = 1, disagree = 2, neutral = 3, agree = 4, and strongly agree = 5. Tables 10-13 display means and medians of student survey responses, with means rounded to the nearest tenth.

As seen in Table 10, collaboration opportunities again emerged at the forefront when calculating means regarding positive student perceptions. All three items addressing collaboration, items 4, 5, and 6, had means higher than 4. These items had the highest means of any statement, except item 7 which involved increased class time for problem set completion. The overall mean for all survey items related to collaboration was 4.4. Items 4 and 6 also had medians of 5, which speaks to the high level of interactions that occurred between peers and with the teacher during the flipped classroom intervention.

Table 10

Measures of Central Tendency for Survey Items Related to Collaboration

Item	*N*	*M*	*SD*	*Min*	*Mdn*	*Max*
4. When the classroom was flipped, I spent more time working with classmates.	41	4.4	0.673	3	5	5
5. I understand the problem sets (worksheets) better when I work with a classmate.	41	4.3	0.807	2	4	5
6. The flipped classroom allowed for more time to ask the teacher questions in class.	41	4.5	0.840	1	5	5

Means for items related to student engagement were also 4 or higher, with the exception of item 9. The overall mean for all survey items related to student engagement was 3.8. These items are found in Table 11. On item 9, student opinions were mixed on whether video lectures were more engaging than in-class lectures. For item 16, 53.7% of students strongly agreed they took notes when watching the videos. After items 4, 6, and 7, this was the largest percent of students who strongly agreed with a statement, thus giving item 16 a median of 5 as well.

Table 11

Measures of Central Tendency for Survey Items Related to Student Engagement

Item	*N*	*M*	*SD*	*Min*	*Mdn*	*Max*
9. I was more engaged watching the videos than I was during in-class lectures.	41	3.1	1.256	1	3	5
15. I pay better attention to the videos when they are made by my teacher versus using pre-made videos from another source.	41	4.2	0.759	3	4	5
16. When I watched the videos, I took notes.	41	4.0	1.448	1	5	5
17. I am able to focus better when the lecture is broken into smaller parts.	41	4.0	0.935	1	4	5

Besides item 7, all other items related to student learning and academic achievement (see Table 12) received mean scores below 4 and minimum scores of 1. However, all of these items also received a maximum score of 5, which indicates at least one student strongly agreed with each statement. The overall mean for all survey items related to learning and academic achievement was 3.8. Again, it seems there were more varied opinions on items related to learning and academic achievement during the flipped classroom intervention than those items related to collaboration and engagement. If items 11-14 in Table 13 are disregarded, items 9 and 10 have the lowest means at 3.1. Items 8, 9, and 10 have the lowest medians at 3. The overall category means for engagement and learning/academic achievement were both 3.8, while the category mean for collaboration was 4.4. This is consistent with interpretation of data from Tables 6-8, which indicates students did not feel as positive about increased engagement during videos or learning through videos as they did about collaboration opportunities.

Table 12

Measures of Central Tendency for Survey Items Related to Student Learning and Academic Achievement

Item	*N*	*M*	*SD*	*Min*	*Mdn*	*Max*
1. The video lectures helped me understand math concepts.	40	3.9	0.810	1	4	5
2. I would rather watch a video lecture for homework than do math problems for homework.	41	3.9	1.300	1	4	5
3. I prefer the flipped classroom over the traditional classroom format.	41	3.5	1.186	1	4	5
7. The flipped classroom allowed more time to complete problem sets (worksheets) in class.	41	4.8	0.435	4	5	5
8. When the classroom was flipped, I understood the problem sets (worksheets) better.	41	3.5	1.003	1	3	5
10. I learned better through the videos than I did through in-class lectures.	41	3.1	0.932	1	3	5
18. I want to continue learning math in the flipped classroom format.	41	3.6	1.204	1	4	5

In all four survey items related to watching video lectures, as seen in Table 13, at least one student “strongly disagreed” and at least one “strongly agreed”. This again speaks to the individualized pacing video lectures provide. Some students often paused or rewound videos, while some rarely did. Others regularly fast forwarded lectures, while some did not speed them up. The median for item 14 is lower than the median for items 12 and 13, which indicates more students slowed down the video versus sped it up. The overall mean for all survey items related to watching the videos was 3.4.

Table 13

Measures of Central Tendency for Survey Items Related to Watching the Videos

Item	*N*	*M*	*SD*	*Min*	*Mdn*	*Max*
11. I watched the video lectures prior to class.	41	3.7	1.039	1	4	5
12. I often paused the videos when watching them in order to process the content.	41	3.5	1.098	1	4	5
13. I rewound some videos or watched them more than once.	41	3.2	1.406	1	4	5
14. I fast forwarded the videos when watching them.	41	3.0	1.225	1	3	5

The student survey concluded with two open-ended questions. Question 19 read, "What did you like about the flipped classroom? Describe any aspects of the flipped classroom that helped you learn better than the traditional classroom format." I read through student responses and identified themes, citing the frequency of student responses according to each theme. These data are in Table 14.

Four themes directly related to the learning environment emerged from this question about benefits of the flipped classroom. The learning environment theme with the highest frequency involved students appreciating more time in class to complete problem sets. One student noted, "It sure beat listening to a lecture for a good chunk of class and then forgetting what you learned when it came to doing the homework." About one quarter of students cited learning at their own pace as a benefit. One student wrote, "I liked how I could pause the video and try doing equations my own speed instead of in a classroom where others blurt out the answer before I figure it out." Another wrote, "I liked that I could set my pace. I could pause the video and rewind it when I needed to. Plus all of the information was pretty straight forward." A third said, "If I understood a topic quicker I could do things at my pace." Five students communicated a less stressful or more flexible educational environment. One student remarked there were "fewer tears shed over 'impossible' problems ☺," while another said "I really looked forward to class because it was a lot less stressful." Another student wrote, "I personally enjoyed being able to go home and just needing to watch the videos and take notes."

Table 14

Student Responses to Item 19

Theme	Frequency
More time to ask questions/get help	22
More time in class to complete problem sets	22
Helpful to work with peers	15
Could learn at own pace	10
Less stressful/more flexible learning environment	5
More interested/engaged in the math	4
Easy to catch-up if absent	4
Videos helped with understanding	3
Watching videos for homework was less time consuming than completing problem sets for homework	3
Could review concepts by re-watching videos	2
Could focus better during videos versus an in-class lecture	2

Two themes related to collaboration opportunities emerged from student responses to question 19. Providing more class time for students to ask questions and get help was one of the most prevalent themes. One student commented, "I understood the material way better than the original style because I could ask any questions I wanted to and get help on my homework during the day rather than zero help at night." Other students echoed this response by writing, "It was helpful when we had time to ask questions because during in-class lectures there wasn't much time for that," and, "I liked the fact that you could get questions answered right away."

Finding it helpful to work with peers was also a common theme. One student wrote, “I really liked doing the worksheets in class, because I could work with my partner then and by combining what we both knew and didn’t know we both (or at least, I did) better understood the material.” Another stated, “It helped to hear how to do the problems from a peer.” Still another wrote, “I feel like flipping the classroom gave me the ability to compare/check my answers with other people rather than an answer key.”

Two common themes were connected to student engagement. About 10% of students cited increased interest or engagement in math as a benefit of the flipped classroom. One student shared, “I’m more engaged doing the worksheets in class rather than at home.” A second wrote, “It helped me when we discussed a problem or tried to figure it out on our own.” Two students conveyed the ability to focus better during videos versus in-class lectures. “I really liked how the lectures were short and to the point- sometimes in-class lectures can be drawn out the whole class period, and I lose interest.”

No themes were cited that directly related to increased student achievement on assessments given during the flipped classroom intervention period. However, three additional themes emerged that were not directly related to my research questions. These included ease of catching up if absent, having the ability to review concepts by re-watching videos, and spending less time watching videos for homework compared to completing problem sets for homework. One student wrote, “I really liked that if I forgot a concept I was able to go back and look at the videos for guidance.”

The second open-ended question, and last question on the student survey, related to negative aspects of the flipped classroom. Question 20 read, “What did you not like about the flipped classroom? Describe any aspects of the flipped classroom that hindered your learning compared to the traditional classroom format." Student responses were again themed and are located in Table 15.

Table 15

Student Responses to Item 20

Theme	Frequency
Easy to get behind if videos weren't watched (including absences)	9
Some videos were difficult to understand	9
Can't ask questions or interact with the teacher during the video lectures	7
Hard to find time to watch the video every day	7
Some videos were too long	6
Did not like watching videos for homework	5
Videos needed more examples	2
Experienced computer problems when attempting to access video	2
Group/partner dependency	2
Would forget to watch the videos	2

Of the 10 negative themes that emerged, 9 had to do with some aspect of the video. Nine times students referred to falling behind from not watching video lectures. It is interesting that a few of these comments included people being gone for absences, considering four people cited videos as a benefit after being absent. One student wrote, "As long as you watched the video you were okay, otherwise it was hard." A second noted, "If you didn't watch the video for that lesson, the next day's worksheet was confusing." Nine students also indicated some videos were hard to understand, with three of those specifically mentioning the videos on logarithms. One student wrote, "I suggest not doing logarithm videos because they were very confusing." It should be noted that students had no prior knowledge of logarithms, which was a large portion of chapter seven. They did have prior knowledge of exponent properties, which was a main concept in chapter six.

The next most frequent negative theme was not being able to interact with the teacher during video lectures. Seven students made similar statements, including, "I did not like how I couldn't ask questions as I was learning the material on the video," and, "I didn't like the interaction of the videos compared to the classroom format." Seven students also communicated it was hard to find time to watch the video every day, while six said the videos were too long. One student commented, "Sometimes there were lots of videos that were really long, and it got to be overwhelming. It can take a long time, especially when you have to pause the video and do problems."

The only common theme for question 20 not related to videos involved dependency on classmates. One student wrote, "Sometimes my partner wouldn't watch the videos or she would fall behind. Then because we were working together, I had to teach her the new lesson which made it take longer for me to do the worksheets." In this instance, not watching the video had a direct effect on collaboration opportunities.

Focus group interview. Qualitative data were also collected through a focus group interview, which was conducted to gain additional information on collaboration opportunities, student engagement, academic achievement, and the flipped classroom learning environment. This interview was conducted the week following completion of the flipped classroom intervention. Five students of various ages, genders, and ability levels gathered and answered questions (see Appendix J) as a group. The group was composed of students who watched video lectures at varying consistencies and collaborated with peers at varying levels.

Questions 4 and 5 dealt with collaboration opportunities. Two students said they worked closely with a partner on the homework assignments. One student said, "I kind of worked with my partner on every worksheet, because like if there was something I didn't get, he would get it, and if he didn't get it, it seemed like I would get it; so we would like benefit from each other. . . . It's kind of like checking your answers," Two other students said they consulted their partner, but not all the time. One noted, "We'd do most of the problems . . . separately and then kind of check each other's stuff, and if there was a problem we didn't get we'd kind of talk through it." Four of the five students said their first instinct was to ask a peer if they had a question. The fifth student said she first checked the answer keys I posted if she had a question. "I like working independently," she said. "I feel I work better that way."

Two of the five students being interviewed pointed out their peers might approach a problem differently than the teacher, and that can be beneficial. "If you [the teacher] explained it one way and I didn't exactly get it they [a peer] might explain it a different way." Another said, "It's easier to understand it in their [peers'] words than your words, because they kind of like, I hate to say it, but like dumb it down. . . . They make it easier to understand in like our mind; . . . we [peers] basically think kind of like each other." A third student piped up by adding it was easier to teach a subject that he understood. Some lessons were easier to explain than others. When asked if they ever got tired of explaining concepts to their peers, none of the students indicated this was the case. "If you explain it to someone, it helps you understand it more," one student stated. "It's just like extra practice." Students being interviewed voiced a comfort level associated with having a choice in the seating arrangement. "It helped how you said that we could pick who we wanted to sit by, and who you worked better with. . . . If you were busy with another student you could ask them [peers] and they would most likely get it, and you're like more comfortable asking them rather than if you have a random person sitting by you." Another student did acknowledge, "We could talk a lot and get off subject."

One student brought up an interesting point when it came to student and teacher interactions during the flipped classroom. At the beginning of class in the traditional setting, I often fielded student questions in the large group. "When people ask questions when you're up doing a lesson [in the traditional setting] it would like take a while. Sometimes if people have a lot of questions and then we kind of just have to like rush through the rest [of the lesson] to finish it, so then like other stuff we don't really understand fully." Answering individual questions in a large group does not always benefit the whole class, and in fact, can eat up valuable class minutes. A different student appreciated having more time to ask individual questions during the flipped classroom. In the traditional setting, she pointed out, "If there are a whole bunch of questions, some questions might not get asked." No students indicated they interacted with me less during the flipped classroom. "With the flipped classroom you'd have all class period to work on homework and you [the teacher] would like make it so you would walk around and talk to every student and see how they were doing, whereas if you are just teaching in the class you don't have that class period to ask questions. . . . You'd have to find time to come in."

Questions 2 and 6 of the interview related to student engagement. Students had mixed responses about which method of instruction held their attention better. Two students said it was easier to pay attention to the video. "It was more like one-on-one," one student pointed out. "You could go at your pace. . . . I thought it was like easier to concentrate when it was like just you." The other noted the video was more focused. "My class gets off topic so easily, but it's like still related to math but not math that we're doing. It's confusing. . . . Some people can understand it [the material] like three days earlier, so then like they ask questions and it just kind of confuses the whole class that's [learning] at a different pace." A third student said either way of learning didn't make much difference. Still a fourth said he paid more attention during traditional lectures as he easily got distracted with other things while watching video lectures.

All five students implied they spent more time thoughtfully completing problem sets when the classroom was flipped. Four of these students alluded to hurrying through problem sets when the classroom was not flipped. "In the traditional classroom, I'd like rush through it [the problem sets] more. . . . When I got home . . . I'd just want to finish it and like get it over with even if I didn't really understand it." A different student acknowledged, "At home I'd just do it just to do it. . . . In the classroom I'd take a little more time to do the problems and work stuff out." Still another said, "You have more time to think about the problems [in the flipped classroom]. . . . If you don't have enough time to do your homework in class, you'd go home and you wouldn't really remember everything and you couldn't really ask anyone."

Question 1 addressed how students watched the videos. A couple students said they watched them every night, while two others said they missed a video every once in a while. A few students indicated they watched the videos in school, with one saying, "It was kind of a lot easier if you had a period off." While recording videos, I often asked students to pause and attempt a problem on their own. Only one student said he regularly paused the videos during this time. The others indicated they just watched me work out problems without trying it on their own first, but would pause at other times to catch up. Surprisingly, no one in the focus group thought the videos were too long. They were in agreement that to keep student attention, maximum video length should be about 25 minutes. The average length of my videos was 16 minutes 20 seconds, with the longest video being 21 minutes 14 seconds and the shortest video being 9 minutes 24 seconds.

Question 7 dealt with student achievement on tests and quizzes. While students were not as vocal about this topic, four of the five stated they performed better on the assessments given during the flipped classroom versus the traditional setting. The fifth student performed about the same. One individual said, "I felt after we did the flipped classroom it was kind of easier on the tests. I understood the topics more."

Interview questions 3 and 10 related to the learning environment. One student said he had more questions during traditional lectures versus video lectures. He again referred to students learning at different paces, and pointed out sometimes material was delivered too quickly in the large group setting. Two others said they also had fewer questions during video lectures. If they did have questions during the video, they were usually answered at some point. One stated, "I feel like I barely had any questions when I could watch the video." While these students seemed to appreciate the focus of the video, a different student indicated he found value in learning from other people's questions during traditional lectures, and this aspect was absent during the videos. "Sometimes during class people ask questions and that brings up a different point that you may have forgotten to go over during the video." Despite any negative feelings, all five students were in agreement that I should flip the classroom more often. Students had minimal additional comments related to interview questions 8 and 9.

Common assessments. Quantitative data were collected through common assessments given to control and experimental classes. The experimental classes consisted of two algebra 2 classes which received content through teacher-made video lectures during third quarter. The control classes consisted of two algebra 2 classes from the previous year which received content through traditional whole class lectures. Statistical analysis of these data aimed to address the research question of whether flipping the classroom had any effect on student achievement.

To show the control classes and experimental classes were academically comparable, data were collected from four quizzes and two tests administered prior to the flipped classroom intervention. Scores from the Measure of Academic Progress (MAP) standardized test were also gathered. For each assessment, a *t*-test of independent samples was conducted.

Table 16 shows results of the descriptive statistics for assessments given before the flipped classroom intervention. Quiz 1.4, 1.5, 2.3, and 2.4 (out of 35 points) covered solving equations, solving inequalities, and linear functions. Quiz 4.5-4.6 (out of 26 points) and the chapter 4 test (out of 56 points) covered quadratic functions and equations. Quiz 5.1-5.3 (out of 28 points) involved polynomial functions, and the 8.4-8.6 quiz (out of 41 points) and chapter 8 test (out of 58 points) dealt with rational functions.

Table 16

Descriptive Statistics of Assessments Given Before the Intervention

	Control Classes			Experimental Classes		
Assessment	*N*	*M*	*SD*	*N*	*M*	*SD*
Quiz 1.4, 1.5, 2.3, 2.4	38	29.184	4.688	38	29.526	4.222
Quiz 4.5-4.6	38	20.355	4.310	38	21.605	3.815
Test Chapter 4	38	47.105	8.811	38	45.832	8.139
Quiz 5.1-5.3	39	23.705	4.062	38	23.474	3.335
Quiz 8.4-8.6	39	33.474	6.271	38	31.737	6.118
Test Chapter 8	39	49.904	8.259	38	49.263	6.735
MAP Mathematics RIT Score	38	256.237	16.562	38	255.500	11.282

Table 17 displays results of the analysis of these assessments. Means of the experimental classes are represented by μ_E, and means of the control classes are represented by μ_C. The null hypothesis was no difference between means of the control and experimental classes, while the alternative hypothesis was a significant difference using a 0.05 significance level. Since the *p*-values of these tests were greater than 0.05, I failed to reject the null hypothesis. This indicated assessment means of the control classes and experimental classes were not significantly different before flipping the classroom. Thus, the two groups were academically comparable.

Table 17

T-Test Results of Assessments Given Before the Intervention

Assessment	Difference	Difference in Sample Means	Standard Error	*df*	*t*	*p*
Quiz 1.4, 1.5, 2.3, 2.4	$\mu_E - \mu_C$	0.342	1.023	73.202	0.334	0.739
Quiz 4.5-4.6	$\mu_E - \mu_C$	1.250	0.934	72.925	1.339	0.185
Test Chapter 4	$\mu_E - \mu_C$	-1.273	1.946	73.539	-0.655	0.515
Quiz 5.1-5.3	$\mu_E - \mu_C$	-0.231	0.846	72.921	-0.274	0.785
Quiz 8.4-8.6	$\mu_E - \mu_C$	-1.737	1.412	75.000	-1.231	0.222
Test Chapter 8	$\mu_E - \mu_C$	-0.641	1.715	72.763	-0.374	0.710
MAP Mathematics RIT Score	$\mu_E - \mu_C$	-0.737	3.251	65.255	-0.227	0.821

During the nine week flipped classroom intervention period, data were gathered from seven assessments and compared to data from the previous year's algebra 2 classes. Again, *t*-tests of independent samples were conducted. Table 18 displays descriptive statistics for each assessment given during the flipped classroom intervention. The 6.0-6.5 assessments covered properties of exponents, rational exponents, radical expressions, and radical equations. Quiz 6.0-6.2a was out of 33 points, quiz 6.2b-6.5 was out of 37 points, and test 6.0-6.5 was out of 62 points. Mini test 6.6-6.8 included material on composite functions, inverse relations, and graphing radical functions, and was out of 25 points. Exponential functions were reviewed in 7.1 and 7.2, while 7.3-7.6 introduced logarithms. Quiz 7.1-7.2 was out of 26 points, quiz 7.3-7.6 was out of 29 points, and the chapter 7 test was out of 67 points.

Table 18

Descriptive Statistics of Assessments Given During the Intervention

	Control Classes			Experimental Classes		
Assessment	*N*	*M*	*SD*	*N*	*M*	*SD*
Quiz 6.0-6.2a	39	28.795	4.100	38	29.250	3.747
Quiz 6.2b-6.5	39	30.641	4.979	38	30.618	5.397
Test 6.0-6.5	39	55.641	5.480	38	55.408	5.823
Mini Test 6.6-6.8	39	20.705	4.285	37	21.176	2.617
Quiz 7.1-7.2	39	21.615	3.739	38	23.079	2.647
Quiz 7.3-7.6	39	23.897	6.277	37	25.216	4.644
Test Chapter 7	39	57.551	9.592	37	58.122	7.294

Table 19 displays results of the analysis of these assessments. Means of the experimental classes are represented by μ_E, and means of the control classes are represented by μ_C. The null hypothesis was no difference between means of the control and experimental classes, while the alternative hypothesis was the experimental classes would score significantly higher than the control classes using a 0.05 significance level. The *p*-values of all but one of these tests were greater than 0.05. On quiz 7.1-7.2 involving exponential functions, the experimental classes scored significantly higher than the control classes. Thus, mean scores of assessments given to the experimental classes during the flipped classroom intervention were not significantly greater than mean scores from the control classes except on one quiz. Therefore, I failed to reject the null hypothesis.

Table 19

T-Test Results of Assessments Given During the Intervention

Assessment	Difference	Difference in Sample Means	Standard Error	*df*	*t*	*p*
Quiz 6.0-6.2a	$\mu_E - \mu_C$	0.455	0.895	74.697	0.509	0.306
Quiz 6.2b-6.5	$\mu_E - \mu_C$	-0.023	1.184	74.156	-0.019	0.492
Test 6.0-6.5	$\mu_E - \mu_C$	-0.233	1.289	74.438	-0.181	0.428
Mini Test 6.6-6.8	$\mu_E - \mu_C$	0.471	0.810	63.409	0.581	0.281
Quiz 7.1-7.2	$\mu_E - \mu_C$	1.464	0.737	68.528	1.986	0.026*
Quiz 7.3-7.6	$\mu_E - \mu_C$	1.319	1.262	69.926	1.045	0.150
Test Chapter 7	$\mu_E - \mu_C$	0.571	1.949	70.710	0.293	0.385

* Indicates significance at the $\alpha = 0.05$ level.

Interpretation of Results

By collecting data through various instruments, I was able to address each of my research questions. The strongest theme emerging from my journal entries, student surveys, and focus group interviews was increased collaboration. Over and over again this was cited as a positive element of the flipped classroom. Out of 26 journal entries I made on days where students were given a new problem set, 24 of them contained descriptions of students working with one another. The three student survey questions addressing collaboration had the highest means of any statement, except the somewhat obvious statement about increased problem set completion time. The most frequent themes of survey item 19 were more time to ask questions or get help from the teacher, more time to complete problem sets, and finding it helpful to work with peers. Again, two of the top three positive aspects of flipping centered on collaboration opportunities.

Focus group participants echoed this theme, as they made many positive comments about working with peers or having time to ask questions.

It should be noted that 82.9% of students either agreed or strongly agreed with item 5 from the survey, which stated, "I understand the problem sets (worksheets) better when I work with a classmate." Only 48.8% of students agreed or strongly agreed with item 8, which stated, "When the classroom was flipped, I understood the problem sets (worksheets) better." Perhaps this discrepancy can be attributed to the fact that a handful of students each day had to watch the video during class as they had not done so prior, which reduced peer collaboration opportunities. Falling behind with video lectures was one of the most frequently occurring themes for item 20 of the survey, which addressed negative aspects of the flipped classroom. This theme was also found throughout my journal entries. Another note that should be made is 30 students regularly worked with a peer, while 11 worked on a more individual basis. Data indicate collaboration is perhaps the most beneficial aspect of the flipped classroom, and about 75% of students regularly engaged in conversations with peers.

Another survey discrepancy should be noted. Item 10 on the student survey revealed only 34.1% of students said they learned better through video lectures, while 43.9% were neutral. However, item 18 revealed 61% wanted to keep learning math through the flipped classroom format. It seems delivery of content in the flipped classroom was similar to the traditional classroom, but interaction students had with problem sets was the main variable. Perhaps these two survey items reflect the desire students have for increased collaboration opportunities.

Survey item 9 revealed 46.3% of students were more engaged while watching video lectures versus in-class lectures, while 24.4% did not indicate a change in engagement level, and 29.2% did not feel more engaged. These responses, coupled with survey responses to item 10, cause some hesitation when drawing conclusions about video lectures increasing engagement. It was especially concerning that nine of the top ten negative themes emerging from survey item 20 related to the videos. I can conclude however, that students appreciated the self-pacing aspect video lectures provided. In the free response portion of survey item 19, ten of forty-one students indicated they appreciated the ability to learn at their own pace. While most survey and focus group comments related to pacing involved pausing or rewinding videos, some also appreciated the ability to fast forward through material. This appreciation for control over the pacing of learning was an unanticipated, yet important research result.

Although results were mixed concerning student engagement levels while watching video lectures, I can conclude with confidence that students were more engaged during class time when the classroom was flipped. Increased engagement seems to be a direct byproduct of increased collaboration opportunities. After ceasing the flipped classroom and returning to traditional lecturing, the classroom seemed somewhat dull. Students who regularly participated in small group discussions during the flipped classroom contributed minimally, if at all, to large group discussions. In fact, one of my most engaged students became noticeably withdrawn. It became more obvious to me that a handful of students controlled large group discussions, whereas the majority of students contributed to small group conversations during the flipped classroom.

After conducting *t*-tests, it could not be concluded that flipping the classroom was tied to increased overall academic performance. While problem set completion rates rose, gains on assessments were not visible at a statistically significant level except on one assessment. However, it should be noted that when analyzing assessments given before the intervention period, mean scores of the control classes were higher than the experimental classes for five of the seven assessments. When analyzing assessments given during the nine weeks the classroom was flipped, mean scores of the experimental classes were higher than the control classes for five of the seven assessments. Survey item 1 also revealed 87.5% of students thought video lectures helped them understand math concepts. I can confidently conclude that flipping the classroom did not hurt overall academic performance.

Summary

Before flipping my classroom, I was wary of student acceptance. Students initially complained when presented with the idea, but once implemented, positive comments far outnumbered the negative. The main drawback was about one quarter of students did not watch the videos before class.

In the end, my data analysis results were in line with my hypotheses. On average, about 36 fewer minutes of classroom time each day were spent on delivering content and instead devoted to completion of problem sets. I anticipated students would appreciate opportunities to work with each other and ask me questions, thus being more engaged during problem set completion time. After analyzing student surveys, focus group interview data, and my journal entries, collaboration and engagement during problem set completion time were the most obvious positive results. I did not expect the flipped classroom to drastically improve academic performance, but I hoped there would be no obvious negative consequences. The data collected through common assessments supported this hypothesis.

Chapter Five

Conclusions, Action Plan, Reflections, and Recommendations

In previous years, a typical day in my algebra 2 classroom involved me being in front of the room fielding questions and presenting the lecture for at least 70% of the class time. By flipping the classroom, I hoped students would have additional time to interact with each other and me on a more individual basis, thus increasing student engagement and possibly student achievement. In this chapter, I reflect upon the flipped classroom intervention and the results of my research as they relate to my future teaching career.

Conclusions

The main research question focused on the impact flipping has on the learning environment. On average, students had 36 more minutes to complete problem sets in the flipped classroom versus the traditional classroom. Delivering content through videos allowed for this change. It should be noted about one quarter of students did not consistently watch video lectures outside of class. In a typical day, a handful of students instead watched the video during class, thus missing out on collaboration opportunities.

For the majority of students who watched the videos, collaboration opportunities seemed to be the main benefit of the flipped classroom. Approximately 90% of students spent more time working with classmates when the classroom was flipped, and nearly 83% indicated they understood the problem sets better when working with a classmate. About 90% of students also reported they had more time to ask the teacher questions when the classroom was flipped versus the traditional style. One of the sub-questions of my research was "Does flipping the classroom reduce lecture time in class, and as a result, allow for more interactions with and amongst students?" After gathering data during the flipped classroom intervention, I can confidently answer yes to both parts of this question.

As a teacher, observing students collaborate with one another was the most rewarding part of the flipped classroom. I realized it was okay to give up control. After the flipped classroom intervention, it became quite obvious I did not need to be the only source for disseminating information. Most students were willing to explain mathematical concepts to a peer, and could sometimes communicate information in a more easily understandable manner. Instead of immediately asking me for help, students regularly turned to a classmate. Many great conversations about mathematical processes occurred during the flipped classroom, thus increasing student engagement during problem set completion time. A handful of students verbalized that when they completed problem sets at home, they did so just to get them done. In the flipped classroom, students had more time to reflect on problems and address misconceptions.

The last sub-question of my research was, "Does flipping the classroom increase student engagement and achievement?" Students were noticeably more engaged with problem sets, but I cannot confidently report they were more engaged with video lectures. While about 46% of students said they were more engaged watching video lectures versus in-class lectures, approximately 29% disagreed with this statement while the rest were neutral. A few students expressed they appreciated being able to ask questions during traditional lectures, whereas that opportunity was not available during video lectures.

Regarding student achievement, I am unable to report increased academic gains with any level of statistical significance except on one quiz. Control classes outperformed experimental classes on the majority of assessments compared before the flipped classroom intervention, while experimental classes outperformed control classes on the majority of assessments given during the flipped classroom intervention. However, only one of these gains was large enough to be considered statistically significant. Generally, I was pleased with academic performances of the experimental classes and did not observe any glaring negative effects.

One unexpected research outcome related to pace of the learning environment. In the free response portion of the survey, pace was the fourth most frequent positive theme. Without being prompted to do so, nearly one quarter of the students in the experimental group made some positive comment related to learning at their own pace. Five additional comments were made about the learning environment being less stressful or more flexible. This result caused me to reflect on the pressures of a one-pace-fits-all traditional classroom atmosphere. Many students felt anxiety in a math setting, and the more individualized pace of the flipped classroom seemed to alleviate some of this strain.

Action Plan

On day four of the flipped classroom, the first line of my teacher observation journal read, "Sometimes I miss having control." After concluding the flipped classroom intervention, I went back to traditional lectures and realized how dull the class seemed. A quiet classroom where the teacher is controlling the learning process is not necessarily a good thing. After analyzing student surveys, I realized most students agreed with this notion. I could not ignore the fact that 61% of students wanted to keep learning math through the flipped classroom format. I also noted 19.5% of students did not want to keep learning math through the flipped classroom format. Therefore, I decided to flip the last unit of the year on sequences and series, but teach the trigonometry chapter through traditional methods.

In future years, I plan to record more video lectures. It seems units containing review material are conducive to flipping. During the intervention period some students verbalized it was difficult to learn logarithms through video lectures, as they had no prior knowledge of the concept. I hesitate to flip chapters containing brand new or very involved concepts. For example, I have no plans to teach geometry proofs through videos. I do plan to use video lectures for days I am gone. As a track coach, this will be a valuable resource.

When I flip in the future, I plan to follow a format similar to the nine week algebra 2 intervention. It worked well to randomly select students to share their answers to problem set questions. Having students come to the whiteboard was a form of accountability. I will again let students choose their seats to encourage collaboration. In the future I will consider creating a forum where students can post questions about the video lectures, and try to keep videos to 15 minutes in length.

Reflections and Recommendations for Teachers

Each classroom is different. Methods that work well with one group of students may not work as well with another. At the end of the nine week flipped classroom intervention, one of my classes seemed to be thriving. Students were collaborating at high levels and were fairly independent. I had strong leaders in this class who were able to explain mathematical concepts and keep groups focused. As a whole, my other class did not engage in mathematical conversations to quite the same extent. There were not as many debates involving how to solve problems. More students in this class chose to work independently, and occasionally checked in with a peer if they had a question. This class had more absences toward the end of the intervention period, which caused collaboration levels to decrease. By the end of the nine weeks, they seemed ready for a change.

Flipping the classroom was a success in both experimental classes, even though some students were ready for traditional lectures to return. This method of instruction was a great way to increase student collaboration and engagement with problem sets. For educators thinking about flipping their classroom, I encourage them to thoughtfully plot out which units work best with video lectures. About 80% of my students indicated they paid better attention to videos made by their teacher versus videos from another source. Taping lectures can be time consuming, but worth it. I suggest starting with one unit. Videos should be concise, as students can always pause or rewind them. It takes a few days for students to get in the routine of the flipped classroom, so it should be a fairly sustained practice. Switching back and forth between video lectures and traditional lectures could get confusing. I personally do not plan to flip during the first month of school. I need time to get to know my students and establish a comfort level in my classroom.

Before implementing the flipped classroom, I had conversations with colleagues about the process. One science teacher from a neighboring school flipped his classroom and emphasized communicating with parents. I certainly agree that it is important to relay goals and expectations of the flipped classroom to parents. This teacher even suggested calling home if students failed to watch video lectures prior to class. As expected, lack of video-watching was the most glaring negative aspect of flipping. Another colleague suggested having students fill out guided notes while watching videos, then checking them for points. While I appreciated this suggestion, I did not create guided notes. I do not provide my students with guided notes in the traditional classroom, as I find value in high school students being able to identify important lecture information. If I were to flip the classroom with younger students, I may consider this resource. I also did not call parents, although I will consider this in the future for students who regularly come unprepared to class. During the flipped classroom intervention, I more heavily relied on peer accountability to encourage video-watching. If one student did not watch the video, it came at the expense of peer collaboration. As with any teaching method, it is important to establish a routine, reflect on the process, and make changes if necessary.

For me, positive effects of the flipped classroom far outweighed the negative. I would suggest flipping to most any educator, as long as their students have access to technology. I especially encourage flipping in classes where students are willing to engage in conversations about the content, or for teachers looking for a change of pace. After flipping, I am more confident students can teach each other, and this enhances learning. Students who never contributed to whole class discussions actively participated in the learning process during the flipped classroom. Every flipped classroom is unique; no formula exists to perfect this instructional practice. However, it seems the flipped classroom holds too much potential to be just another passing fad.

Summary

Typically, I am not someone who embraces change. At first mention of the flipped classroom, many students did not embrace change either. However, as an educator I understand the importance of trying new instructional methods. Through flipping, I realized students could learn without me standing in front of the classroom for forty minutes each day. Observing students regularly engage in mathematical conversations was exciting. Being able to touch base with students every day, instead of frantically answering questions in a small amount of time, was a relief. Collaboration, engagement, and more individualized pacing are benefits of the flipped classroom I cannot ignore.

I plan to flip my classroom again in the future. More than likely I will flip for certain chapters, not the entire year. Some mathematical topics require more guided practice, some are more conducive to learning by doing, and others are more favorable for independent learning. By intentionally using a variety of instructional methods, I hope to positively influence the learning environment.

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Appendices

Appendix A

School Principal Consent Form

Dear Dr. Bertsch:

I am completing work toward the Master of Arts in Teaching: Mathematics degree through Minot State University. As a degree requirement, I am to conduct a research project in my classroom this year during third quarter. I am planning to analyze student survey, interview, and assessment results to determine what effects flipping the classroom has on the learning environment. Specifically, I will be looking at collaboration with and amongst students, student engagement, and student achievement. To accomplish this, I would like to work with students in my sixth and seventh period algebra 2 classes. I chose my algebra 2 classes as they all have tablets.

During this time, I will tape 10-15 minute videos covering the same material I would normally teach during class. Watching these videos will be assigned as homework. The following day I will finish up the lecture in class, and students will have time to work on problem sets. At the conclusion of the study, students in my algebra 2 classes will complete a survey and some will be interviewed concerning the effectiveness of the flipped classroom. I will be keeping a daily journal, and will record how classroom minutes are spent. Also, quiz and test scores from this year's algebra 2 students and last year's algebra 2 students will be used for data analysis along with problem set completion rates. Classroom and student confidentiality practices will be observed regarding all data collected, and no individual will be identified by name.

Before the study begins, I will send home consent forms for parents/guardians to notify them of this project and request their permission, allowing their student to participate in the research study. Student consent forms will also be administered. A copy of these letters is attached for your inspection.

I am requesting you permit me to carry out this research in my classroom. Please contact me if you have any questions. Thank you for your consideration.

__X__ I grant permission for Jessica Myxter to conduct the above mentioned research in her classroom.

_____ I do not grant permission for Jessica Myxter to conduct the above mentioned research in her classroom.

Todd D Bertsch

Signature of Dr. Todd Bertsch, Principal at Fargo South High School

11-11-2013

Date

Appendix B

Associate Superintendent of Teaching and Learning Consent Form

Rece... - F...
OCT 3 1 2013

AF 4800

RESEARCH STUDY REQUEST

I hereby request permission to conduct a research study in the Fargo Public School District during the period from January 13, 2014 to March 19, 2014.

TOPIC: The Effects of Flipping the Classroom on Classroom Environment and Student Achievement

If this request is granted, I agree to abide by **ADMINISTRATIVE POLICY 4800:**
(refer to the FPS web site at www.fargo.k12.nd.us)

Signature of Researcher Jessica Myster

Institution of Higher Education Minot State University

Signature of Graduate Advisor Laurie Geller

Date 10/29/2013

In addition to completing the Research Study Request Form,
a copy of the following items are attached for review:

1. Abstract of the project
2. Questionnaire(s) to be used
3. Consent letter to be sent to parents

Endorsement: This request is X approved ___ disapproved

Administrator: [signature]

Date________________

A copy of this approval form must be presented to the school building principal before conducting any survey. The principal has the final approval to conduct a survey in a school building.

Please print your name and the mailing address where you want this form returned:

Name: Jessica Myster

Street Address: Fargo South High School

City, State & Zip: ________________

Appendix C

IRB Approval Letter

Minot State UNIVERSITY
1913 2013 Our Place. Our Legacy. Our Vision.

Institutional Review Board

Notice of IRB Approval

Name of Principal Investigator: Laurie Geller

University Address: *Mathematics and Computer Science*

Title of Project: The Effects of Flipping the Classroom on Classroom Environment and Student Achievement

Protocol Number: 1346

December 2, 2013

The above project has been reviewed and approved by the IRB under the provisions of Federal Regulations 45 CFR 46.

This approval is based on the following conditions:

1. The materials you submitted to the IRB provide a complete and accurate account of how human subjects are involved in your project.
2. You will carry on your research strictly according to the procedures as described in materials presented to the IRB.
3. You will report to the chair of the Institutional Review Board any changes in procedures that may have a bearing on this approval and require another IRB review.
4. If any changes are made, you will submit the modified project for IRB review.
5. You will immediately report to the IRB Chair any problems that you encounter while using human subjects in your research.

Dr. Bryan Schmidt

Chair, Minot State University's IRB

500 University Ave W, Minot, ND 58707 701-858-3594 1-800-777-0750 FAX 701-858-4260

Appendix D

Parent/Guardian Consent Form

Effects of Flipping the Classroom on Learning Environment and Student Achievement

A Research Project by Jessica Myxter

Invitation to Participate

Your child is invited to participate in a study involving the flipped classroom. Flipping the classroom centers on students watching video lectures for homework. In turn, this often allows more time to complete problem sets in class.

Purpose of the Research

I am currently completing work towards my Masters of Arts of Teaching: Mathematics degree through Minot State University. For my final degree requirement, I am conducting this action research project during quarter three to determine if flipping the classroom changes the classroom environment. Specifically, I will be focusing on student and teacher collaboration levels, as well as student engagement and achievement.

Basis for Subject Selection

Your child has been selected for my study because he/she is in algebra 2. As an algebra 2 student, your child has a school-issued tablet that can be used to watch video lectures. Many of the concepts studied during quarter three lend themselves nicely to the video lecture format.

Duration of Participation

This study will be conducted during the third quarter, which begins January 13th, 2014 and ends March 19th, 2014.

Specific Procedures

Due to the large amount of material covered in algebra 2, much of the class period is devoted to lecturing. After the lecture, students may have a few minutes to get started on the problem set as I circulate around the room. During third quarter, I will tape 10-15 minute videos which will replace part of the in-class lecture. In class I will lecture on any additional material not covered in the video if needed. Then, students will have time to work on the problem set. Student homework will include watching the video prior to the next day's lesson, and completing the problem set if they do not finish in class.

At the end of the quarter students will complete a survey on the environment of the flipped classroom. Some students may also be interviewed for their opinions. Survey responses, interviews, my observations, classroom minutes, homework completion rates, and assessment (quiz and test) results will be analyzed to determine whether the flipped classroom affects collaboration, student engagement and achievement levels, and the overall classroom environment. Results will be summarized and included in my research paper. No students will be identified in my results. This research study has been approved by the district office.

Benefits and Risks to the Individual

There are no direct benefits to participating in this study, but the data collected will be used to help improve the classroom environment. The risks to your student are no more than he/she would encounter in a regular classroom setting.

Confidentiality

The researcher (myself) will treat all data confidentially. All data including student assessments, problem sets, surveys, and interviews will be kept safe in a locked cabinet or on my password-protected computer. All data will be destroyed once the paper has been defended. The researcher agrees to maintain strict confidentiality, which means your name and your student's name will not be discussed or given to anyone. The researcher will also make sure confidential information will not be discussed in an area that can be overheard that would allow an unauthorized person to associate or identify the student with such information.

Voluntary Nature of Participation

During this study, survey responses and interviews do not have to be included. However, I hope you approve of your student being involved in this study because a large sample size improves the accuracy of the results of my study. If you decide to participate, you are free to withdraw your consent at any time during the study. If you do not consent or withdraw your consent, your student's data will not be included in my results, your student will not complete the survey nor be interviewed, but your student will still participate in the flipped classroom as it is part of the course work.

Human Subject Statement

The Institutional Review Board of Minot State University has given me permission to conduct this research. If you have questions regarding the rights of research subjects please contact the Chairperson of the MSU Institutional Review Board (IRB), Dr. Bryan Schmidt, at 701-858-4250 or bryan.schmidt@minotstateu.edu.

Offer to Answer Questions

If you have any questions or concerns now or during the study, please contact me at myxterj@fargo.k12.nd.us.

Consent Statement

You are voluntarily making a decision whether or not to participate in this study. With your signature below, you are indicating that upon reading and understanding the above information,

you agree to allow your student's survey, interview, problem set, and assessment results to be used in this study. You will be given a copy of this consent form to keep.
Thank you for your consideration.

____
Participant (Please Print Student's Name)

____________________________________ ____________
Signature of Parent or Guardian Date

____________________________________ ____________
Signature of Researcher Date

Appendix E

Student Assent Form

Effects of Flipping the Classroom on Learning Environment and Student Achievement

A Research Project by Jessica Myxter

Invitation to Participate

You are invited to participate in a study involving the flipped classroom. Flipping the classroom centers on students watching video lectures for homework. In turn, this often allows more time to complete problem sets in class.

Purpose of the Research

I am currently completing work towards my Masters of Arts of Teaching: Mathematics degree through Minot State University. For my final degree requirement, I am conducting this action research project during quarter three to determine if flipping the classroom changes the classroom environment. Specifically, I will be focusing on student and teacher collaboration levels, as well as student engagement and achievement.

Basis for Subject Selection

You have been selected for my study because you are in algebra 2. As an algebra 2 student, you have a school-issued tablet that can be used to watch video lectures. Many of the concepts studied during quarter three lend themselves nicely to the video lecture format.

Duration of Participation

This study will be conducted during the third quarter, which begins January 13th, 2014 and ends March 19th, 2014.

Specific Procedures

Due to the large amount of material covered in algebra 2, much of the class period is devoted to lecturing. After the lecture, you may have a few minutes to get started on the problem set as I circulate around the room. During third quarter, I will tape 10-15 minute videos which will replace part of the in-class lecture. In class I will lecture on any additional material not covered in the video if needed. Then, you will have time to work on the problem set. Homework will include watching the video prior to the next day's lesson, and completing the problem set if you do not finish in class.

At the end of the quarter you will complete a survey on the environment of the flipped classroom. Some of you may also be interviewed for your opinions. Survey responses, interviews, my observations, classroom minutes, homework completion rates, and assessment (quiz and test) results will be analyzed to determine whether the flipped classroom affects collaboration, student engagement and achievement levels, and the overall classroom environment. Results will be summarized and included in my research paper. No students will be identified in my results. This research study has been approved by the district office.

Benefits and Risks to the Individual

There are no direct benefits to participating in this study, but the data collected will be used to help improve the classroom environment. The risks to you are no more than you would encounter in a regular classroom setting.

Confidentiality

The researcher (myself) will treat all data confidentially. All data including student assessments, problem sets, surveys, and interviews will be kept safe in a locked cabinet or on my password-protected computer. All data will be destroyed once the paper has been defended. The researcher agrees to maintain strict confidentiality, which means your name will not be discussed or given to anyone. The researcher will also make sure confidential information will not be discussed in an area that can be overheard that would allow an unauthorized person to associate or identify you with such information.

Voluntary Nature of Participation

During this study, survey responses and interviews do not have to be included. However, I hope you approve of being involved in this study because a large sample size improves the accuracy of the results of my study. If you decide to participate, you are free to withdraw your consent at any time during the study. If you do not consent or withdraw your consent, your data will not be included in my results, you will not complete the survey nor be interviewed, but you will still participate in the flipped classroom as it is part of the course work.

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Offer to Answer Questions

If you have any questions or concerns now or during the study, please contact me at myxterj@fargo.k12.nd.us.

Consent Statement

You are voluntarily making a decision whether or not to participate in this study. With your signature below, you are indicating that upon reading and understanding the above information,

you agree to allow your survey, interview, problem set, and assessment results to be used in this study. You will be given a copy of this consent form to keep.
Thank you for your consideration.

____
Participant (Please Print Student's Name)

______________________________________ ____________
Signature of Participant Date

______________________________________ ____________
Signature of Researcher Date

Appendix F

Sample Algebra 2 Problem Set

Name______________________________

6.1 Roots and Radical Expressions

Find **all** the real square roots of each number. In other words, which real numbers squared produce the given number?

1. 400
2. -121
3. 0.0049

Find all the real cube roots of each number. In other words, which real numbers cubed produce the given number?

4. $\frac{1}{216}$
5. -125
6. -0.064

Evaluate the expressions if possible over the set of **real numbers**. Recall the radical sign indicates you are looking for the principle root, so you should only have one answer.

7. $\sqrt{144}$
8. $-\sqrt[4]{16}$
9. $\sqrt{-0.01}$
10. $\sqrt[5]{0.00001}$
11. $\sqrt[3]{-27}$
12. $\sqrt{0.09}$

Simplify each radical expression, assuming all variables are nonnegative and nonzero.

13. $\sqrt{81x^4}$
14. $\sqrt{121y^{10}}$
15. $\sqrt[3]{8g^6}$
16. $\sqrt[3]{125x^{18}}$
17. $\sqrt[5]{243x^5y^{15}}$
18. $\sqrt[3]{(x-9)^3}$

19. $\sqrt[5]{\frac{32}{x^{10}}}$

20. $\sqrt[3]{\frac{64x^9}{216}}$

21. $\sqrt[3]{-0.008x^{12}}$

22. $\sqrt[4]{\frac{x^4}{81}}$

23. $\sqrt{36x^2y^{14}}$

24. $\sqrt{25(x+2)^4}$

25. The volume of a cube is 8,000 cubic centimeters. What is the length of each of the sides?

26. The voltage V of an audio system's speaker can be represented by $V = 4\sqrt{P}$, where P is the power of the speaker. An engineer wants to design a speaker with 400 watts of power. What will the voltage be?

Find the two real solutions of each equation.

27. $x^2 = \frac{0.16}{49}$

28. $x^6 = 64$

29. $x^4 = \frac{16}{625}$

30. How many imaginary solutions does #28 have? How about #29?

31. Simplify $\left(\frac{8x^2x^{-4}}{2x^6}\right)^3$

Appendix G

Sample Algebra 2 Quiz

Name________________________________

Quiz 6.0-6.2a
Algebra 2- Myxter
Show your work as partial credit will be given! NO CALCULATOR

1. Simplify the expressions completely, writing all answers with positive exponents.

a) $\left(3x^5y^4x^2\right)^3 =$ ____________

b) $\dfrac{x^2z}{x^{-4}z^5} =$ ____________

c) $\left(\dfrac{2x^0}{5x^{-2}}\right)^{-3} =$ ____________

d) $16^{\frac{-1}{2}} =$ ____________

2. Find all real cube roots of each number if possible. In other words, what numbers cubed equal the given number?

a) -64 ____________

b) 8 ____________

3. Simplify the following:

a) $\sqrt{0.81} =$ ________

b) $\sqrt[3]{-125} =$ ________

c) $32^{\frac{1}{5}} =$ ________

4. Cross out any of the equations below that are not true:

$\sqrt[5]{3}\cdot\sqrt[5]{6} = \sqrt[10]{18}$

$\sqrt[3]{7}\cdot\sqrt[4]{7} = \sqrt[12]{7}$

$\sqrt{3}\cdot\sqrt{11} = \sqrt{33}$

Simplify the radical expressions **completely**. Assume all variables are nonnegative and nonzero. Circle your answer so I can find it please! ☺

5. $\sqrt[4]{16x^{24}y^{8}}$

6. $\sqrt[3]{32x^{5}y^{10}}$

7. $\dfrac{\sqrt{20x^{16}}}{\sqrt{5x^{2}}}$

8. $\sqrt[5]{6x^{3}y^{2}} \cdot \sqrt[5]{16x^{4}y}$

Bonus Solve the equation $x^{\frac{3}{4}} = 8$

$x =$ ____________

Appendix H

Sample Algebra 2 Test

Name________________________________

Test 6.0-6.5
Algebra 2- Myxter NO CALCULATOR
Read all directions and show your work as partial credit will be given!

Simplify the expression completely, leaving no negative exponents. Assume all variables are nonnegative and nonzero.

1. $\left(x^3\right)^6$ = __________

2. $\dfrac{x^4 x^{-3}}{x^{-8}}$ = ___________

3. $y^{\frac{1}{3}} \cdot y^{\frac{2}{5}}$ = _________

4. $\left(x^{\frac{-1}{2}} \cdot y^{\frac{3}{4}}\right)^8$ = _________

5. $\left(\dfrac{1}{16}\right)^{\frac{-1}{2}}$ = __________

6. $27^{\frac{2}{3}}$ = ___________

Evaluate the following:

7. $\sqrt[4]{16}$ = ________

8. $\sqrt[5]{-32}$ = ________

9. $\sqrt[4]{625^3}$ = _________

10. Simplify the radical expression $\sqrt{75}+\sqrt{12}$

____

11. Cross out any equations below that are not true.

$\sqrt[3]{8}\cdot\sqrt[5]{8}=\sqrt[15]{8}$ $\quad$ $4\sqrt{3}+7\sqrt{2}=11\sqrt{5}$ $\quad$ $\sqrt{6}\cdot\sqrt{7}=\sqrt{42}$

Simplify each expression completely. Assume all variables are nonnegative and nonzero.

12. $\sqrt[3]{64a^6b^{12}}$

13. $\sqrt{50x^2y}$

14. $\sqrt[4]{4x^3}\cdot\sqrt[4]{8xy^{10}}$

15. $\sqrt[3]{40x^{14}y^2}$

16. $\dfrac{\sqrt{10x^{12}}}{\sqrt{2x^2}}$

Simplify the expressions, making sure to rationalize the denominator. Assume all variables are nonnegative and nonzero.

17. $\dfrac{\sqrt{5x^4y}}{\sqrt{7x^7y}}$

18. $\dfrac{10}{7-3\sqrt{2}}$

Find all real solutions.

19. $\sqrt[3]{x-3}+4=6$

20. $2x^{-4}+3=165$

$x=$ _______________

$x=$ _______________

21. $5(y+1)^{\frac{2}{3}} = 45$

22. $3x^{\frac{-5}{3}} = 96$

$y =$ ______________

$x =$ ______________

23. $\sqrt{x+7} = x+1$

$x =$ ______________

Bonus (from the 2009-2010 ACT practice test)

In the real numbers, what is the solution of the equation $8^{2x+1} = 4^{1-x}$?

$x =$ __________

Appendix I

Flipped Classroom Student Survey

I have designed this survey to receive feedback on student perceptions of the flipped classroom model and its effects on the classroom environment. Please take your time and answer the questions truthfully. This is an anonymous survey so do not write your name on it. Thank you!

For each statement 1-18, indicate your level of agreement by checking one box that best aligns with your opinion and experience.

Strongly Disagree (SD)	Disagree (D)	Neutral/No Opinion (N)	Agree (A)	Strongly Agree (SA)

Item	**SD**	**D**	**N**	**A**	**SA**
1. The video lectures helped me understand math concepts.					
2. I would rather watch a video lecture for homework than do math problems for homework.					
3. I prefer the flipped classroom over the traditional classroom format.					
4. When the classroom was flipped, I spent more time working with classmates.					
5. I understand the problem sets (worksheets) better when I work with a classmate.					
6. The flipped classroom allowed for more time to ask the teacher questions in class.					
7. The flipped classroom allowed more time to complete problem sets (worksheets) in class.					
8. When the classroom was flipped, I understood the problem sets (worksheets) better.					

Item	SD	D	N	A	SA
9. I was more engaged watching the videos than I was during in-class lectures.					
10. I learned better through the videos than I did through in-class lectures.					
11. I watched the video lectures prior to class.					
12. I often paused the videos when watching them in order to process the content.					
13. I rewound some videos or watched them more than once.					
14. I fast forwarded the videos when watching them.					
15. I pay better attention to the videos when they are made by my teacher versus using pre-made videos from another source.					
16. When I watched the videos, I took notes.					
17. I am able to focus better when the lecture is broken into smaller parts.					
18. I want to continue learning math in the flipped classroom format.					

19. What did you like about the flipped classroom? Describe any aspects of the flipped classroom that helped you learn better than the traditional classroom format.

20. What did you not like about the flipped classroom? Describe any aspects of the flipped classroom that hindered your learning compared to the traditional classroom format.

Appendix J

Student Interview Questions Guide

1. How often did you watch the videos?

    a) When did you usually watch them?

    b) Where did you usually watch them?

    c) Did you watch the whole video continuously from start to finish? Explain.

2. Did you pay closer attention during the lecture when the classroom was flipped, or did you pay closer attention during the lecture in the traditional setting? Explain.

3. Did you have more questions during the lecture when the classroom was flipped, or did you have more questions during the lecture in the traditional setting? Explain.

4. Did you interact with me (the teacher) more or less when the classroom was flipped?

    a) What did these interactions look like?

    b) Do you feel you learn better when there is more time to interact with me (the teacher)?

5. How often did you work with another student when completing problem sets (worksheets) in the flipped classroom versus the traditional classroom?

    a) If you work with a peer, does this help you learn better than if you work on your own? Explain.

6. Overall, did you spend more time thoughtfully completing the problem sets (worksheets) when the classroom was flipped? Elaborate.

7. How do you feel you performed on tests and quizzes while the classroom was flipped versus the traditional setting?

a) If there was a noticeable difference in your performance, what would you attribute the change to?

8. What did you like about learning through the videos?

a) How did your understanding of the material in the flipped classroom compare to the traditional setting?

9. What did you dislike about learning through the videos?

a) Is there anything you would like to see me change about the flipped classroom in the future?

10. Do you think I should flip the classroom in the future? Why or why not?

a) Should I flip the classroom the whole year, or only for certain chapters?