



Flipping the High School Mathematics Classroom: The Reception, Perception, and Criticism From Students

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Flipping the High School Mathematics Classroom: The Reception, Perception, and
Criticism from Students

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A Thesis in the Field of Mathematics for Teaching
for the Degree of Master of Liberal Arts in Extension Studies

Harvard University

November 2017

Abstract

Since its start in 2007, the flipped classroom has grown in popularity among secondary school educators as resources have developed and as more students have gained access to technology. This thesis investigates how students perceive and respond to the pedagogical decision of mathematics teachers to modify their classroom structure from a traditional classroom style to the flipped classroom style so that future teachers can mitigate potential disadvantages of the latter.

In this study, the researcher surveyed students in three Precalculus classes throughout their first flipped unit on Right Triangle Trigonometry and the Unit Circle, and gathered data about their homework habits, opinions on the advantages and disadvantages of each instructional model, and on how they perceive their own engagement.

The results of the final survey showed a mixed response in student preference of instructional style. From the students' point of view, the main advantages of the flipped format were time spent collaborating in class with the teacher and peers, and the ability to learn content at their own pace. The largest perceived disadvantage was the lack of the ability to ask questions during initial knowledge acquisition.

The results of this study can help math teachers who are planning to flip their classrooms by providing insight into their students' thoughts and concerns before and during their instruction. Incorporating student-perceived advantages and planning for

anticipated concerns allows teachers to more effectively transition to the flipped classroom instructional style and more effectively facilitate student learning.

Author's Biographical Sketch

Seth McNaughton graduated from Owen J. Roberts High School in 2009 and earned a Bachelor of Science degree in Secondary Physics Education from the Pennsylvania State University in 2012. He currently teaches high school math and computer science in the Phoenixville Area School District.

Acknowledgements

I would first like to thank my thesis advisor Srdjan Divac for his encouragement and thoughtful insight on this project. He put a considerable amount of time into helping polish this piece into something I could not have done alone.

Thanks to Andy Engelward, who inspired me to challenge my students with a variety of puzzles and helped me in the planning phases and the development of the proposal for this thesis.

This work is also a testament to my parents, Daniel and Amy, who have taught me how to love unconditionally and whose lives have demonstrated the importance of higher education.

Finally, a huge thank you to my wife, Rachel, who has been an unwavering source of support and overflowing joy during the challenges of graduate school, coaching, and teaching. I truly could not have completed this without you, and am thankful for having you in my life.

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Chapter I.

Introduction

Whether due to illness, sports, activities, or to family vacations, student absenteeism wreaks havoc on classroom instruction. In each subject, teachers must find a way to help catch students up on the content they missed. In a 2007-2008 survey completed by the National Center for Education Statistics, the national average daily attendance was 91.1 percent of the total enrollment at the secondary school level (Digest, 2011). In 2007, Jon Bergmann and Aaron Sams, two chemistry teachers at a rural district of Colorado, began recording their PowerPoint slide-show lectures with voice-overs and posting the videos online so that absentee students could get a full understanding of the missed content (Bergmann & Sams, 2012).

Bergmann and Sams explain that this sparked the idea that students physically need teachers most when they are stuck on a problem, not necessarily when content is delivered (Bergmann & Sams, 2012). The authors further explain how this generated the foundation of the first flipped classroom; they pre-recorded the videos for the students to watch and take notes on at home and, instead, used the regular class periods for labs and practice problems.

Flipping the classroom, as the name indicates, occurs when students learn the general content of the course outside of the allotted class time, usually by actively watching pre-recorded videos by their own teacher or another teacher (Hamdan, McKnight, McKnight, and Arfstrom, 2013). The practice problems and exercises that would have been attempted at home are instead completed during the face-to-face class

time so that the teacher, and peers, can give immediate and active feedback throughout. Viewing the instructional methodology in terms of Bloom's revised taxonomy in 2001, the students ideally gain the lower levels of knowledge (remembering and understanding) on their own. Students practice the higher level skills (applying, analyzing, evaluating, and creating), while simultaneously having more direct access to the instructor (Brame, 2013).

The shift from a traditional classroom to a flipped classroom can be viewed in many ways as a transition from a behaviorist to a constructivist approach in terms of the use of allotted in-class time. Behaviorism refers to a theory of learning which focuses on the observable and measurable changes in behavior (McInerney, 2014). Behaviorists conclude that given the correct environmental stimulus, students would obtain equivalent learning (Weegar & Pacis, 2012). In a mathematics classroom, a behaviorist could measure the change in a student's ability to solve procedural problems such as the evaluation of an expression correctly applying the order of operations. In contrast, constructivists view learning as a search to obtain meaning and an understanding of the world through unique personal experience. When students are required to solve a new problem without an explicit prior model, students use their prior knowledge to generate a solution (McInerney, 2014).

In regards to educational technology, behaviorism can be traced to the idea of a teaching machine constructed by B. F. Skinner (1958). Skinner suggested that a programmed machine could replace teachers to keep pace with the demand of a growing population. Skinner describes the practicality of such a device by saying, "In using the device the student refers to a numbered item in a multiple-choice test. He presses the

button corresponding to his first choice of answer. If he is right, the device moves on to the next item; if he is wrong, the error is tallied, and he must continue to make choices until he is right” (Skinner 1958). Educational software packages appear to have their roots in Skinner’s teaching machine as do the instructional videos used for the flipped classroom. This automated instruction utilizes ‘operand conditioning’ to impart the basic level of knowledge.

Similarly, in a traditional math classroom, teachers typically present concepts but then require the primary hands-on practice to be completed at home. One common teaching model employed in a traditional classroom is the gradual release of responsibility, a term coined by Pearson and Gallagher (1983). Under this model, the teacher incrementally transitions from explicit modeling of a skill to student independence (Pearson & Gallagher, 1983). When students are taught through the lecture style of a behaviorist’s traditional classroom, it is likely that the students will learn more about the procedural content and less about the conceptual content (Weegar & Pacis, 2012).

Although the traditional classroom can be modified to incorporate constructivist philosophy, the flipped classroom naturally flows from this mindset. A flipped classroom teacher is able to guide the learning in-class rather than directly teaching procedures and delivering knowledge to the students (Feyzioglu, 2012). The flipped classroom model exemplifies constructivist learning by eliminating the traditional lecture from the classroom and by providing students with increased opportunities to ask questions that connect to their own memories and experiences. The knowledge developed in this way has a contextual component which allows it to be more meaningful and causes students to

build on their understanding of concepts and apply this knowledge in a supportive setting (O'Malley, 2015). A flipped classroom teacher becomes a facilitator of the students' learning, as opposed to being the integral hub required for knowledge to be imparted.

With the prevalence of internet access, computers, and other technology in homes, there is an increased ability to create and utilize the flipped classroom model to teach courses. According to a national survey, 48 percent of 2012 teachers reported that they had flipped at least one lesson; however in 2014 that number grew to 78 percent (Sophia, 2015). Not only are there more teachers who have flipped a lesson, but administrators are beginning to expect new teachers to have the ability to implement this instructional model. Project Tomorrow, a nonprofit education group, reported that in the 2014 Speak Up online survey, 46 percent of school leaders indicated that pre-service teachers should be able to set up a classroom using the flipped classroom model (Project Tomorrow, 2015). In the results of the same survey, Project Tomorrow reported that only 12 percent of teachers had not heard of flipping the classroom. With the sudden increase in popularity, one may wonder whether there is data to support the flipped classroom model as a dominant instructional practice.

Although there is limited, experimental research on the effectiveness of the flipped classroom model, there are several case studies and testimonials from teachers, parents, and administrators about its success rate. For example, at Byron High School in Minnesota, math teachers incorporated the flipped classroom method and saw the math mastery increase from 29.9 percent in 2006 to 73.8 percent in 2011 on the Minnesota Comprehensive Assessments (Fulton, 2012). In another case study at Clintondale High School in Michigan, teachers implemented a flipped model and found that the math class

failure rate decreased from 44 percent to 13 percent, and now the entire school runs on the flipped classroom model (Clintondale, 2013). A third example is found in Gerald Overmyer's dissertation in which he studied the effectiveness of the flipped classroom model in a college algebra class (Overmyer, 2014). In his study, five sections of college algebra were taught using the flipped classroom model while six were taught using the more traditional method of lecture during class with homework to be completed outside of class. Overmyer found that although the difference in the scores of the students in the two groups was not statistically significant, the flipped sections did score better overall than students in the traditional sections and instructors with previous classroom experience in cooperative learning strategies had sections with statistically significant higher common final exam scores. While the flipped classroom model was not the only change in each of the three cases mentioned above, it certainly is worth investigating as a potential aid to student success.

According to the 2014 Speak Up survey, one of the largest barriers to the utilization of a flipped classroom is the concern for the students' access to videos away from school (Project Tomorrow, 2015). Internet access available outside the class period is indeed a crucial component of the success of the flipped classroom model. Although there are differences in availability depending on household income, education, and age, 74.4 percent of Americans reported having access to the internet at home (File & Ryan 2014). Furthermore, according to a Pew Research study, 95 percent of teenagers between the ages of 12 and 17 use the internet (Madden, Lenhart, Duggan, Cortesi, & Gasser, 2013). If there are students who cannot watch the videos at home, teachers can make arrangements with their school to allow these students to access the school's computer

lab or library before or after the school day begins. Lack of internet access may be a limiting factor for some teachers in districts with limited technology in schools and homes. However by making creative accommodations for the affected students, more teachers are able to implement a flipped classroom environment.

The 2014 Speak Up survey indicated that there are two additional obstacles teachers face when implementing a flipped classroom model in their classroom. The first challenge is the time and availability for teacher training on how to create videos and how to implement the classroom structure. The second is the required, initial startup time to prepare for a new method of teaching and to develop instructional videos (Project Tomorrow, 2015). In order to counteract these concerns, there is a growing online community of people willing to share their experiences and tips with other ‘flippers’. There are also several free online resources available (lesson plans, videos, and activities), specifically designed for a flipped classroom environment in order to help ease the transition. Nonetheless, trying to replicate a technique, without first experiencing the model as a whole can pose a challenge to teachers who want to do it effectively. To improve alternative instructional methods, teachers will find it beneficial to look at the adjustment not only through the lens of a teacher or administrator, but also consider how instructional methodologies are received and perceived by students and use their feedback to help make improvements for future lessons.

In order for teachers to have the most success when flipping their classrooms, they must be able to clearly articulate what is expected of their students both inside and outside of the class period. In addition, it is helpful for students to understand the reasons why the teacher is trying something new. According to an experienced ‘flipper’, teachers

should spend a class session talking with students about what they can expect from the videos, how students can benefit from this setup, and how crucial it is to come to class prepared (Panopto, 2015). After these explanations, students will undoubtedly have many thoughts, opinions, and possibly fears about the change in teaching style. The flipped classroom can be daunting for students who are comfortable and familiar with the traditional lecture style. On the other hand, it may also be empowering to students who struggle to keep up during the traditional lectures/discussions and freeing to the top students who have difficulty remaining engaged while their peers pepper the teacher with questions. As a teacher, it would be beneficial to know approximately what percent of students feel excited or concerned, and to what extent, by being presented with the flipped classroom model, and how that perception changes as they experience a unit utilizing this technique.

In *The 7 Habits of Highly Effective People* (Covey, 2004), his fifth habit is “Seek First to Understand, Then to be Understood,” in which he explains that in order to help someone else or effectively interact with them, one must first completely understand the other’s perspective and be able to communicate it back to them (p.235). Teachers are in the business of offering advice and suggestions to students on a daily basis and therefore should always be seeking to understand their students in order to be effective, whether employing a traditional instructional method or a flipped classroom. This study hopes to capture the feelings of students before, during, and after a unit that is completed entirely through the flipped classroom model so that teachers can be more effective educators.

Similar Research

With the increase in popularity of the flipped classroom model, there have been several studies published seeking to determine the extent of its adoptions as well as its effectiveness. Usage rate information has been gathered and published by the Flipped Learning Network, showing the increase in recognition of the term “flipped learning” from 73 percent to 96 percent between 2012 and 2014 (Hamdan, McKnight, McKnight, and Arfstrom, 2013). Bishop and Verleger surveyed the current research and conclude that the majority of the current research is exploring student perceptions from a single-group design (Bishop and Verleger, 2013). When research is performed using a single-group design, it makes it impossible to definitively attribute change to the effect of the flipped environment as there is no control group. According to their research, students typically prefer classroom time to be spent on interactive, hands-on activities rather than on lecturing (Bishop and Verleger, 2013).

Graham Johnson published his Master’s Thesis entitled *Student Perceptions of the Flipped Classroom* in which he examined how students perceived the flipped classroom when it was used to promote self-paced pacing and mastery learning of math (Johnson, 2013). In his study, mastery learning was defined as attaining a 70% on each of three electronically graded quizzes in a unit. Students who scored below a 70% would need to discuss their results and complete quiz corrections before retaking another electronic quiz on the same material with different questions. Students could not move forward without passing the quiz and “mastering” a topic. In this particular study students reported spending less time outside of school on homework, and that they believed they had higher engagement level during the classroom activities; however students also noted that

they preferred the videos to be more interactive by having them include, throughout the video, questions that checked their understanding. As a result, the videos created for this research project were designed with questions embedded in the videos which automatically pause the video and require a response from the viewer before continuing. This thesis has similar themes to Johnson's study, although it differs in that the classroom was not be set up for mastery learning, nor could students take quizzes online and at their own pace. Instead, it followed a more traditional classroom pace with traditional quizzes in class.

Chapter II.

Project Description

For this project, the researcher surveyed students in three Precalculus classes throughout their first flipped unit on Right Triangle Trigonometry and the Unit Circle, and used surveys to gather data about their homework habits, opinions on the advantages and disadvantages of each instructional model, and on how they perceive their own engagement. Of the three surveys, the first gathered an initial baseline of their perception of their current study habits, the second gauged the students' anticipation of how the flipped classroom will affect their learning and the specific aspects of the new instruction model components they perceive to be most beneficial, and the third was a reflection on the students' experiences as well as to share their opinions with any teachers who are considering flipping their classes

General Overview of the Study

The research was completed by flipping three Precalculus classes taught by the researcher at a high school in suburban Philadelphia during an entire unit over three weeks of the 2016-2017 school year. The three classes had class sizes of 17, 20, and 29 and had students from grades 9 through 12. The change to a flipped classroom took place over the unit on Right Triangle Trigonometry and the Unit Circle. This unit had sections on solving right triangles using the definitions of sine, cosine, and tangent, solving trigonometric word problems and word problems using bearings/headings, the unit circle, and evaluating trig functions using the unit circle.

Before this unit, the researcher had never flipped his classroom so his experience resembles that of a first time flipper. He had aspirations of creating all instructional videos himself and wanted to be sure that the teaching covered the content that is most similar to what the students would receive had the instructional style not deviated from the traditional classroom environment. After seeing the amount of time required while creating a few videos, the researcher decided to use some videos created by others if any of good quality were already available.

Jon Bergmann, one of the pioneers of the flipped classroom movement, suggests a time limit on the videos of around a minute and a half per grade level (Bergmann & Sams, 2012). Since the students in the researcher's Precalculus classroom are in high school, in accordance with Bergmann's recommendation, the videos in this project were kept no longer than 10-15 minutes each. To help make the videos interactive, the online learning environment, PlayPosit, was used. This electronic resource allows the instructor to embed questions, called video bulbs, at teacher-designated time stamps in the video. These video bulbs require an input from the student before the video continues to play. Students were typically assigned to watch one, but never more than two of these videos each night, totaling around 15 minutes of running video time. Class time was spent using different methods to actively engage students including higher level application questions to solve with a group, open-ended exploratory labs, and other practice problems with an emphasis on student-centered learning where the teacher is able to circulate and assist as needed.

The introduction of the flipped classroom was carefully planned and presented using the suggestions from Crystal Kirch, a math teacher who experimented with and

implemented the flipped classroom full time for three years before becoming a digital learning coach (Kirch, 2012). Her three key pillars are 1) students manage their own learning, 2) flipping the classroom makes the best use of our face-to-face time, and 3) higher order thinking drives in-class activities.

Students were asked to fill out three anonymous surveys online through SurveyMonkey at various points throughout the flipped classroom experiment. The first survey was given a week before the initial description of the flipped classroom in order to get a baseline of homework habits and current understanding obtained in the traditional classroom environment. The second survey was completed the night the flipped classroom was first described to the students, so that they would be able to share their initial experiences in the context of the description. The information from this survey could be useful in enhancing future presentations to help reduce the fears students face about switching classroom style. The third survey was given after the final assessment given after the unit concluded, to determine whether their perception of the flipped classroom changed over the course of a unit.

My First Flipped Classroom

Before flipping my classroom, I had taught the courses I was teaching in their entirety at least once and was in the maintenance and improvement stage - always tweaking my notes or trying neat, new activities that seemed to make excellent connections to real life understanding. I had heard about flipping the classroom and knew a few other teachers who had tried it with varying degrees of success and wondered if the educational practice would be appropriate or a more effective instructional technique for my Precalculus classes. However, my only personal experience of being

involved in a flipped classroom came through my experience at the Harvard Extension School.

The Harvard Extension School helped prepare me above and beyond the Precalculus content I would be teaching by helping me make connections between Algebra and advanced concepts. I took Math for Teaching Advanced Algebra and Trigonometry as well as Vectors: a Tool for Teaching Algebra, Geometry, and Trigonometry. Each of these courses utilized higher level applications of math while emphasizing the connections to the algebra, trigonometry, and calculus of the content taught during the flipped unit on trigonometry in this study. I also took Introduction to the Calculus B and Differential Equations in which one of the graduate seminar projects was to teach our fellow peers who were also taking the course at a distance. Therefore this lesson required elements of a flipped classroom since we could not teach and interact with a live, physical audience, as we were accustomed.

I also felt I was more prepared to flip my classroom than the average teacher because I have a fair amount of experience making videos. I took several video production courses in high school and created a few short films while spending thousands of hours using Adobe Premiere Pro, Adobe After Effects, Final Cut Pro, Windows Movie Maker, iMovie, Hudl, Camtasia Studio, and others. I figured this would help reduce the steepness of the learning curve associated with the production of the videos used while flipping the classroom.

In preparation for the three week flipped classroom Precalculus unit on Right Triangle Trigonometry and the Unit Circle, I created an outline of what I anticipated the in-class and after-class portions of each lesson would consist (Appendix 4). Using this

outline as a guide, I selected practice problems and activities that went along with each topic in class. I also used the outline to create an overview of the content that would need to be covered in each video in order for the students to have the background knowledge necessary for in-class practice.

In preparation for the unit, I worked to include four main components in each lesson: 1) a video to explain a concept, step-by-step, 2) a brief warmup to review the major concepts from the previous night's video, 3) an in-class activity or set of problems that the students could work through at their own pace, and 4) an extension or a challenging question for the learners who finished the regular classwork early. Figure 2-1 shows the guided notes for the two sample problems students complete while watching the instructional video. Figure 2-2 shows an example of a warmup used to start the class the following day, to reinforce the concepts of angles of elevation and depression before releasing the students to practice a variety of word problems incorporating this skill. Figure 2-3 shows the practice problems involving the same skill set that students were able to work on in class at their own pace. When students arrived at an answer that did not match the key's answer they were to first spend time looking at their own work to see where they could have made a mistake. Next, they could show their work to a friend and see if together they could find a mistake. If both students were stuck on the same problem, they could raise their hands together and the teacher would help clarify the concept or error for both of the students.

Right Triangle Definition Word Problems

Video: Right Triangle Word Problem ~ Sal Khan

- A tiny but horrible alien is standing at the top of the Eiffel Tower (which is 324 meters tall) and threatening to destroy the city of Paris!
- A Men in Black agent is standing at ground level, 54 meters across the Eiffel square, aiming his laser gun at the alien.
- At what angle should the agent shoot his laser gun?
Round your answer, if necessary to two decimal places.



Video: More Challenging Right Triangle Trig Problem

An observer on a sea cliff with a height of 12m spots a shark-fin through a pair of binoculars at an angle of depression of 5° . A few minutes later, the observer spots the same shark at an angle of depression of 7° . To the nearest meter, how much closer has the shark moved to the base of the cliff?

Figure 2-1: Sample problems to complete while watching the video

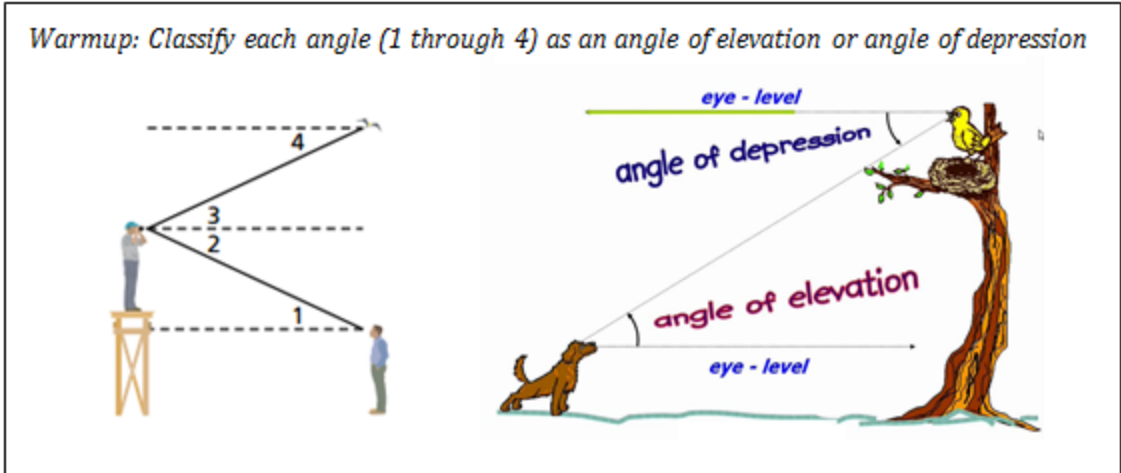


Figure 2-2: Warmup reinforcing a key concept from the previous night's video

On a separate piece of paper, draw and label sketch for each problem and show your work!

Level 1 Problems:

1. For a person looking out a window that is 115 feet above the ground, the angle of depression to the sidewalk below is 64.3° . How far away is the sidewalk along the person's line of sight?
2. If Superman is flying at an altitude of 2000 m and Lois Lane needs an angle of elevation of 46° to see him, how far away is he along her line of sight?
3. When the angle of elevation to the sun is 37° , a flagpole casts a shadow that is 24 ft long. What is the height of the flagpole to the nearest foot?

Level 2 Problems:

4. To estimate the width of a river, an observer first stood directly across the river from a large pine tree. Then she walked 35 m along the river bank until she estimated that the angle between the river bank on her side and her current line of sight to the pine tree was 25° . Find the approximate width of the river.
5. A helicopter pilot looks down at an angle of depression of 40.2° to see the top of a tower. The top of the tower is 300 m away from the helicopter along the pilot's line of sight. If the tower is 40 m tall, what is the helicopter's altitude?
6. The top of a tree was broken off by the wind leaving the lower part of the tree standing with the broken end resting on the stump. The top touched the ground 25 ft from the base of the stump and made an angle of 30° with the ground. What was the tree's original height?
7. The legs of an isosceles triangle are each 21 cm long and the angle between them is 52° . What is the length of the third side?

Level 3 Problems:

8. From the top of a canyon, the angle of depression to the far side of the river is 58° , and the angle of depression to the near side of the river is 74° . The depth of the canyon is 191 m. What is the width of the river at the bottom of the canyon to the nearest meter?
9. From the deck of a ship 25 ft above water level, the angles of elevation to the bottom and top of a lighthouse on a cliff are 41° and 47° , respectively. If the cliff is 678 ft high, what is the height of the lighthouse?
10. A plane is flying at a constant altitude of 14,000 ft and a constant speed of 500 mi/h. The angle of depression from the plane to a lake is 6 degrees. To the nearest minute, how much time will pass before the plane is directly over the lake?

Level 4 Problem:

11. Susan and Jorge stand 38 m apart, both to the west of Big Ben. From Susan's position, the angle of elevation to the top of Big Ben is 65 degrees. From Jorge's position, the angle of elevation to the top of Big Ben is 49.5 degrees. To the nearest meter, how tall is Big Ben?

Figure 2-3: Classwork practice problems implementing the skills learned in the video

For the instructional videos for this unit, I originally wanted to create my own videos that explained a topic, had a sample problem or two, and ideally lasted no longer than 10 minutes with a maximum of 15 minutes per video. In terms of style, I wanted to have pre-created slides that I could write on and add to directly while recording audio narration describing my thought process as I introduced topics, expounded upon concepts, or explained my steps. To this end, I purchased a Microsoft Surface Pro 3 Tablet and Camtasia screen recording software. I also chose to create the slides and present using ActivInspire software that is used with the Promethean Board. After spending time creating the slides, I recorded the narration and added visual effects to highlight particular areas. Surprisingly, between development, narration, visual effects, rendering, and uploading, it took over 12 hours to complete the first video. Figure 2-4 shows a clip from the first instructional video I created with the objective that students would be able to solve right triangles using trigonometry.

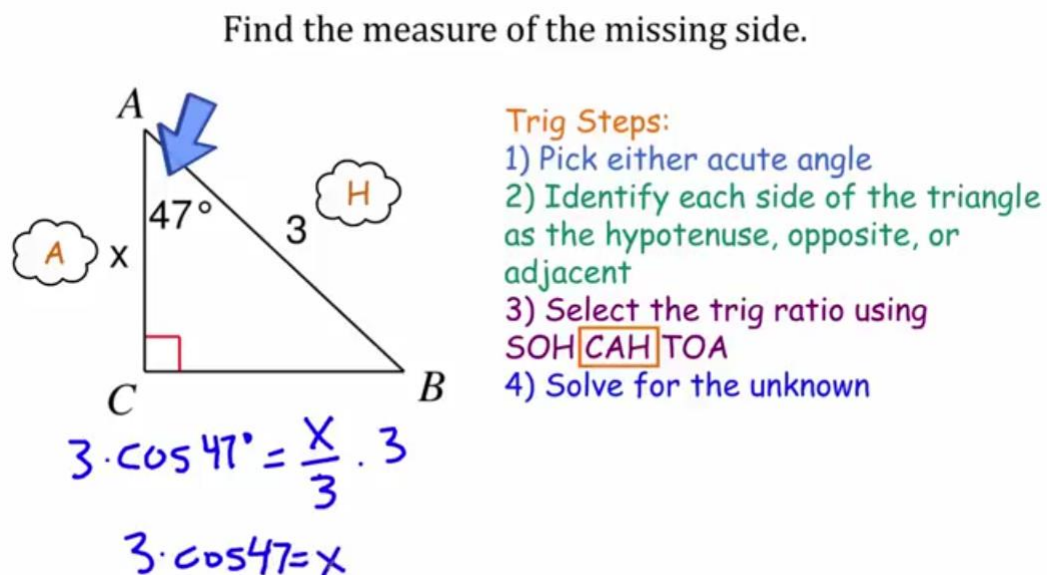



Figure 2-4: Clip from instructional video on how to solve right triangles using trigonometry

Because of the time commitment required to create all fifteen videos with the same quality and the same level of visual effects, I realized this was not a feasible approach for an average teacher flipping their classroom. While I had the skill set to incorporate a variety of visual effects into my videos, I realized that I do not have the requisite time to do so and that most teachers, having less technical know-how than myself, will not be able to include them either. In order to best simulate the average teacher's instructional videos outside the classroom, I resolved to stick to slides, screen capture, and audio narration. I also decided that I would look for, and use, any instructional videos on YouTube that included the relevant material for each lesson and were similar in style to those that I intended to create.

I then created a class through PlayPosit, an online learning environment designed to create and share interactive video lessons. I designed what the site calls "video bulbs" which are videos with interactive questions built in which pause the video until an answer is submitted. I incorporated about four questions per video to either solidify basic vocabulary understanding or to pause the video to allow the student to attempt the problem before seeing the solution. Figure 2-5 shows a small list of the videos as they appear on PlayPosit and Figure 2-6 illustrates the appearance of questions integrated into the video experience.


PRECALCULUS: SECTION 1 SORT BY



Deriving the First Quadrant of the...

Explain how to obtain the coordinates in the unit circle

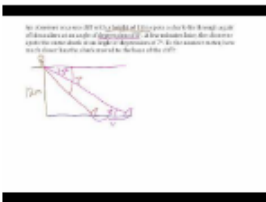
GET ASSIGNMENT DATA



Radians and Degrees

Convert between Radians and Degrees

GET ASSIGNMENT DATA



More Challenging Shark Trig Pro...

Use trigonometry in multiple triangles to solve a word problem

GET ASSIGNMENT DATA

Figure 2-5: Screenshot of videos uploaded to PlayPosit

HIDE QUESTION

Which trig ratio should be used to solve for y ?

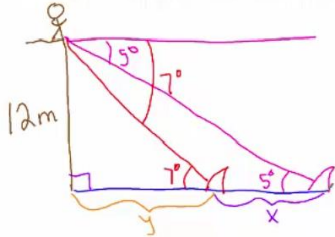
sin

cos

tan

SUBMIT

An observer on a sea cliff with a height of 12m spots a shark-fin through a pair of binoculars at an angle of depression of 5° . A few minutes later, the observer spots the same shark at an angle of depression of 7° . To the nearest meter, how much closer has the shark moved to the base of the cliff?



Q1

07:13

Figure 2-6: Sample video on PlayPosit with integrated questions

Once I had created/found all the videos, added the questions, uploaded them to PlayPosit, and matched up activities to go along with each of the videos, I felt ready to develop my presentation to introduce the flipped classroom to my students.

I started this with the framework provided by Carol Kirch who had been flipping her classroom for a number of years before writing about it in a blog. Based on her experience, she finds it beneficial to for teachers to introduce the flipped classroom while emphasizing the following three pillars to students (Kirch 2012). First, students manage their own learning by watching the videos, asking questions, and by being an active member of the classroom, not simply by being passive observers in the classroom. Second, students focus on the goal of how the flipped classroom is being used to maximize the efficiency of in-class time. Third, in order to make the most of the in-class time, the goal for these activities will be to use higher order thinking skills with the instructor/other peers available to help extend the learning process. By incorporating these focus points into an initial presentation, the goal is that students will feel more ownership of the learning, and not consider this to simply be a mandatory practice they are required to follow.

Over the course of the unit, as certain activities took longer than anticipated, only 11 of the 15 videos were assigned before the unit test as the last four were extensions of the material that would be covered later. The videos had lengths ranging from 4 minutes 43 seconds to 15 minutes 49 seconds and had an average runtime of 8 minutes 14 seconds.

Student Surveys

Data was gathered from students through three different anonymous online surveys through SurveyMonkey. The first was given to gather an initial baseline of their perception of their current study habits, to estimate the amount of time they spend on homework each night on average and on their math homework, to assess the degree to which they believe math that homework helps their learning, to establish the fraction of their nightly homework they can complete correctly without any assistance, as well as the frequency with which they watch additional videos at home to help support their learning (the survey instrument appears in Appendix 1).

After the initial presentation introducing the flipped classroom model, students participated in a second, anonymous, online survey gauging the students' anticipation of how the flipped classroom will affect their learning and the specific aspects of the new instruction model components they perceive to be most beneficial. Additionally, they were able to register their concerns about switching the classroom style and to make a preliminary guess as to which model they felt would best help their learning (the survey instrument appears in Appendix 2).

Once students took the final unit exam they were given one last, anonymous survey in order to reflect on their experiences as well as to share their opinions with any teachers who are considering flipping their classes. Students disclosed the number of videos they watched during the unit, reflected on their actions while watching the videos, compared their experience on practice exercises during the flipped classroom environment, and rated the level of their engagement in each of the two instructional settings. Students were given the opportunity to discuss their perceptions of the

advantages and disadvantages of the flipped classroom, explain if/how their initial perceptions might have changed, and select the model they found best for learning math concepts (the survey instrument appears in Appendix 3).

The students' responses to these surveys provided insight into what they perceived as being beneficial to their learning. The surveys were used to compare the amount of time students spend on homework in a traditional classroom with the amount of time students spend watching videos in a flipped classroom. They were also used to find out if the students' experienced a change in attitude towards the flipped classroom, at some point between the initial and final surveys. Understanding the survey data can help teachers prepare for student responses should they choose to flip their classrooms.

Chapter III.

Results

The results of this study have been divided into three sections. In the first section, the results of the first survey are used to determine study habits and to obtain a baseline of student time and effort. In the second section, the second and third surveys describing preliminary expectations are compared with the perception of the flipped classroom after experiencing it for the unit. Finally, the third section of this chapter describes the teacher's perception of the student engagement and reflection on his first flipped classroom environment.

Survey Results: Study Habits in Traditional/Flipped Classrooms

In the three Precalculus classes, 25 students chose to participate anonymously in the first survey on current study habits, 24 students chose to participate in the second survey, and 15 students chose to participate in the final survey. Because all 66 students in these classes were invited to participate, we cannot claim that this is a random sample that accurately represents this population of students, let alone all students at the high school.

The response to the first survey suggests that while the exact amount varies, students generally have a considerable amount of homework to complete on a nightly basis. According to the survey results in Figure 3-1, 8% spend less than 1 hour, 32% spend 1 to 2 hours, 32% spend 2 to 3 hours, and 8% spend more than 3 hours on homework each night in total. Meaning that, on average, each student spends about 2 hours and 20 minutes on homework each night.

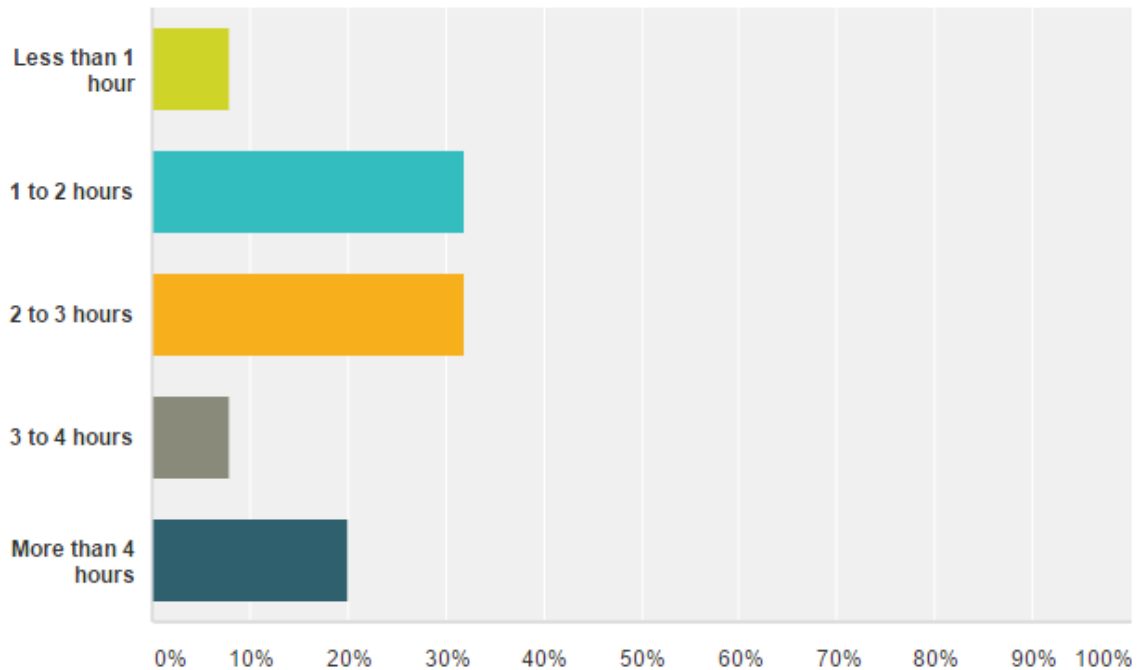


Figure 3-1: Amount of Time Students Spend on Homework Each Evening

Of this time, 8% of students spend less than 20 minutes on math, and 92% of students spend between 20 and 40 minutes on math with the average being around 28 minutes. One student cautioned that their estimate of the time spent on homework be taken with a grain of salt, saying “For the homework, most of that time is procrastination. Most of my math homework is completed during study hall or lunch.” While the reported homework time may include other components such as procrastination and distractions involving friends or technology, it still shows how much time is ‘lost’ to any other competing activity.

The results of these surveys suggest that if flipping the classroom implies keeping the video time to less than 15 minutes, most students could save at least 5 minutes and perhaps even as much as 25 minutes or more each night, which could provide a substantial time savings for students. For example, if 100 homework assignments given

over the course of the year are flipped with instructional videos outside the classroom which save 15 minutes per evening, this would result in a savings of around 25 hours per student, per school year. If the goal of flipping the classroom is achieved and students become more involved in their own learning while spending less time on their homework than they would have spent in a traditional class, then the flipped classroom must be considered a success. If the results of student performance indicate that both instructional techniques result in equivalent student understanding, then the flipped classroom would have an advantage because it achieves the results in less time.

Over the course of the unit, students were assigned 11 videos, averaging a runtime length of 8:14 with a median of 6:23. In the final survey, students reported the amount of time spent on watching the videos each night, and the average time spent watching the instructional videos was over 18 minutes (Figure 3-2). This indicates that they spend more time watching the videos than the simple runtime of the videos would indicate probably due to pausing the videos for practice, for answering the embedded questions, for writing down questions, and for re-watching sections of the video. Students may also include the time it takes to navigate to the videos as part of the time it takes to watch the videos. Nonetheless, it's interesting to see that the time it takes for students to watch the videos during the flipped classroom was over twice as long as the actual run time of the video. As a result, a 10 to 15 minute video could take an average of 20 to 30 minutes to watch and interact with which would result in little, if any time savings.

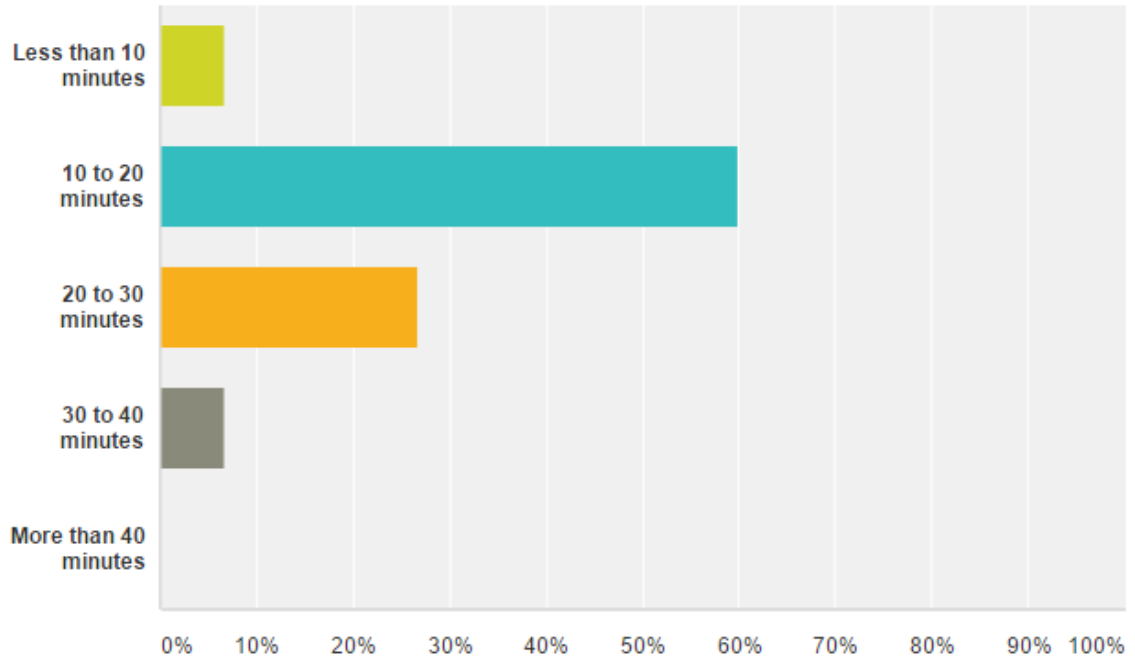


Figure 3-2: Average Time Students Spent Watching Instructional Videos Each Night

The next topic to consider is student engagement in two activities: first, during the initial acquisition of knowledge (lecture or instructional video), and second, during the practice (homework or other assigned practice problems).

In the initial survey on study habits, students were asked how frequently they took notes (Figure 3-3). 60% of students said ‘always’, 28% said ‘often’, while the remaining 12% of students chose sometimes. No students picked ‘rarely’ or ‘never’. In the second survey, when students were asked to predict their notetaking while watching the videos, just 66% of students thought they would take notes. In actuality, according to the results of the third survey, students dramatically altered their note taking habits while watching the videos. Only 29% of students reported that they always took notes, 14% said ‘often’, 29% reported ‘sometimes’, 21% answered ‘rarely’, and 7% never took notes. Even though they were provided with guided notes to follow along with the video, these

numbers suggest a dramatic reduction in note-taking, compared to their own pre-experiment habits, as well as compared to their own anticipations ahead of the experiment. This reduction may suggest that students may see videos as a passive way to gain information rather than an interactive activity in which they are heavily involved. Students may also feel less pressure to copy down every word or number drawn while watching a video knowing that they can always return to that point and re-watch it, whereas in a traditional classroom the opportunity can come and go quickly.

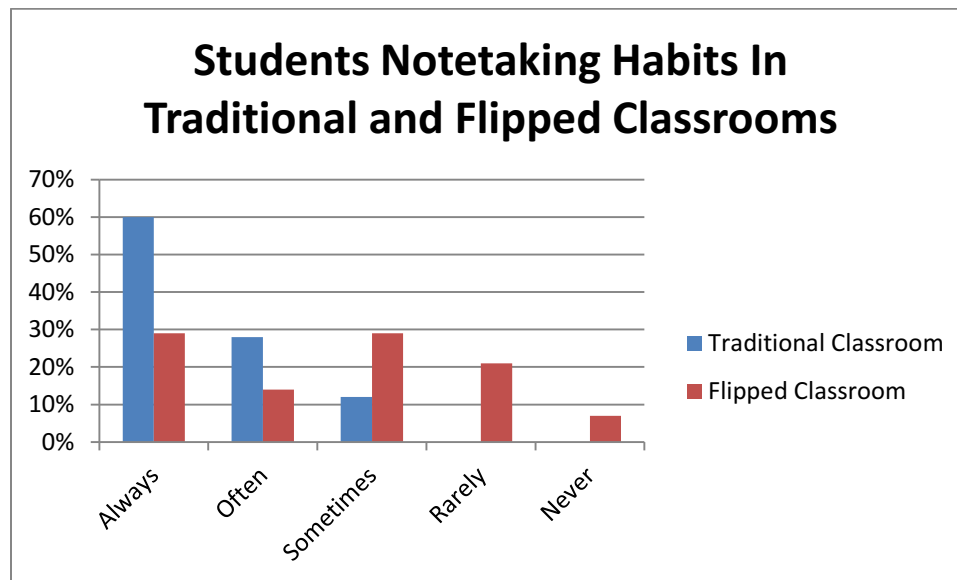


Figure 3-3: Students are significantly more likely to take notes in a traditional classroom rather than by watching an instructional video in a flipped classroom

While some teachers are concerned with students acquiring basic knowledge outside the classroom due to the distractions inherent in the use of technology, students may just as easily be unfocused in the classroom with their attention drifting towards their phones or peers. Comparing the students' reported attention levels in a traditional classroom and the flipped classroom, it is evident that students may even be slightly more

focused while watching an instructional video (Figure 3-4). This may be due to the fact that students choose to watch the instructional video when they are ready, as opposed to being in a classroom and being presented with a topic whether they are ready or not. Students also may feel like they are able to fully engage with a video when they know the short runtime, as opposed to being able to maintain focus for a full 45 minute period.

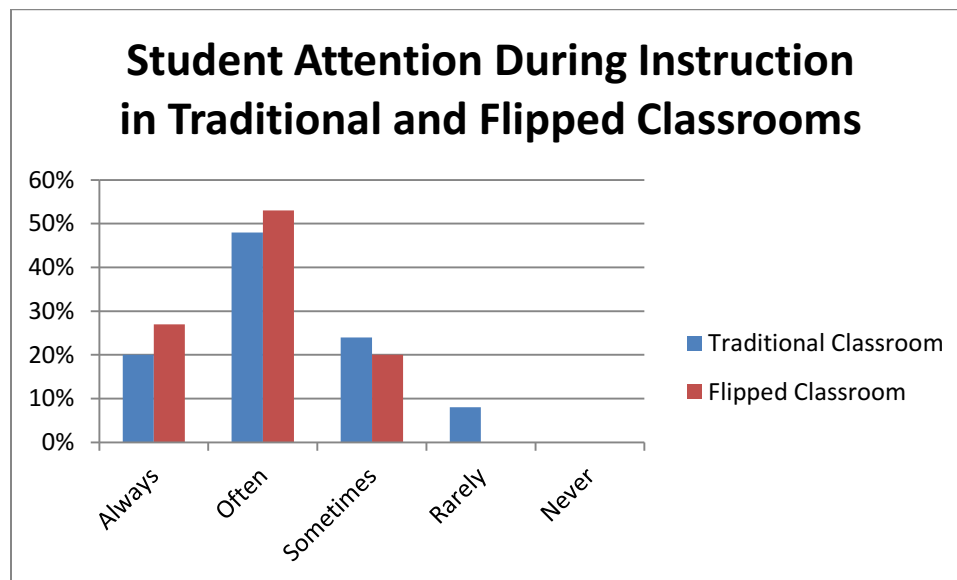


Figure 3-4: Students may be even more engaged while watching an instructional video than during a traditional classroom lecture

In order to understand mathematics, students must be actively engaged in solving the problems, not merely just be sitting back and watching other students solving problems (Protheroe, 2007). This personal, hands-on connection with mathematics happens through homework in a traditional classroom, or in-class in a flipped classroom. Most students agree, as 80% of students said that completing their math homework was often or always beneficial to their level of understanding; only 20% of students thought

math homework was sometimes or rarely valuable. After trying the problems independently, many students run into one or more problems they cannot solve (Figure 3-5). This is the precise moment in which they benefit from a peer or a teacher to answer their questions.

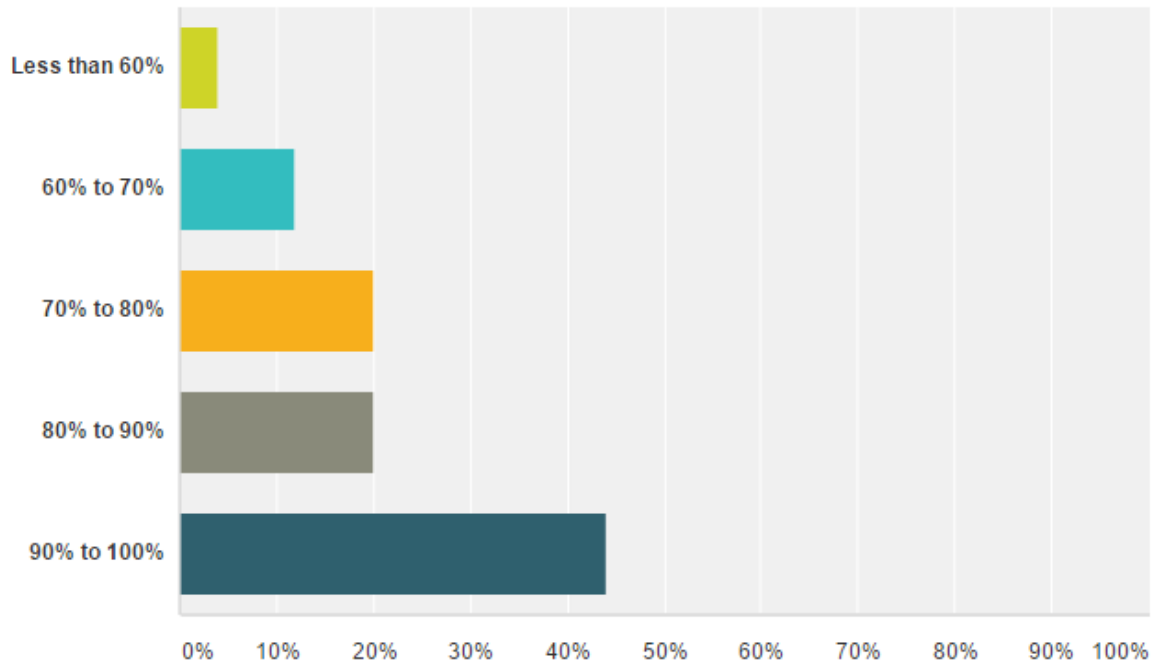


Figure 3-5: Less than half of all students can complete all homework questions without assistance from a teacher or a friend

Many traditional math classrooms are the setting in which homework-related questions are answered – usually at the very beginning of class. However if students are able to receive immediate feedback on a question, they may be able to keep working and have success in future problems. In the survey, 87% of students found working on questions with the teacher and other students to be at least sometimes helpful (Figure 3-6).

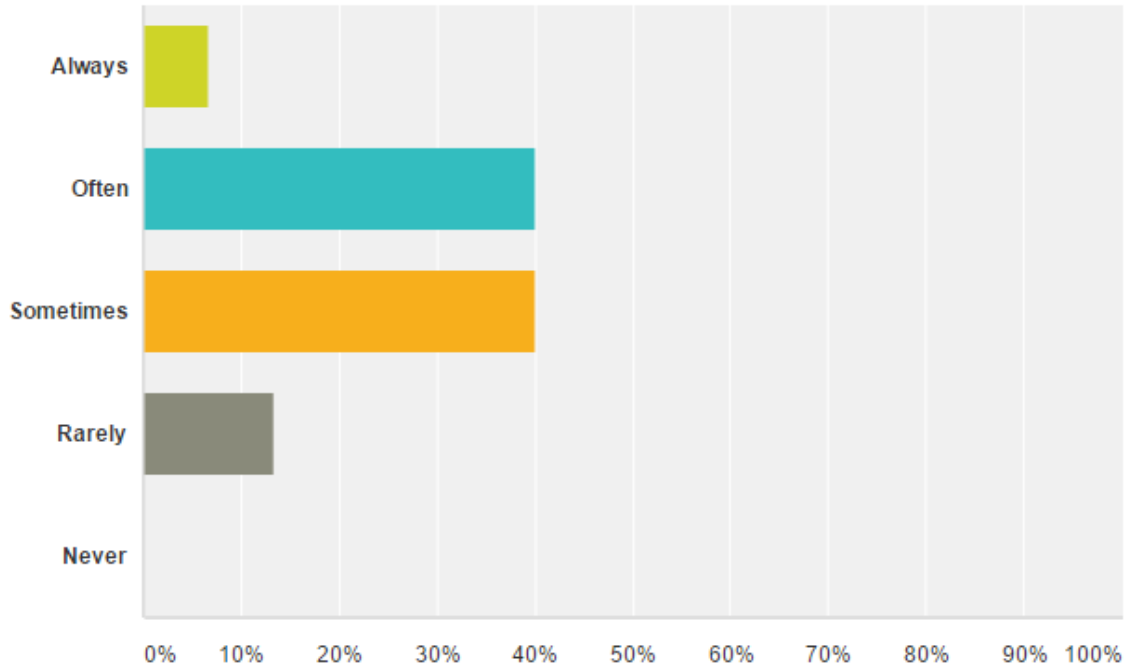


Figure 3-6: Percentages of students who found working on problems in class with support from peers and the teacher to be helpful

Survey Results: Initial and Final Perception of the Flipped Classroom

Students were surveyed the day they were presented about the change from a traditional classroom to a flipped classroom. After the exam for the unit that was flipped, students were surveyed about their perception regarding the flipped classroom to see if any of their opinions had changed as they were exposed to the new style.

When students were surveyed about the advantages of a flipped classroom they were offered opportunities to make multiple selections as well as input open-ended answers. The responses were grouped into four perceived benefits of switching instructional styles and the results are shown in Figure 3-7. First, 72% of students initially thought that the teacher and peers being available for collaboration while practicing and applying new knowledge would be helpful. In the final survey, 87% of

students appreciated the support. This makes sense as the time spent on in-class activities are one of the primary reasons teachers will switch. The second most popular advantage after the presentation was that watching videos outside of school would take less time than completing homework. Initially, 56% of students felt this way, but at the end just 27% perceived this as an advantage. The drop-off is likely due to the fact that the amount of time to watch and work through videos was similar to the time students spent on homework as discussed earlier. Being able to learn the material even when absent from school was the third highest initial perceived perk of the flipped classroom. 52% anticipated that the fact that ‘missing class would no longer prevent one from learning the day’s material’ would be a benefit. In the final survey, just 7% of students found that to be an advantage. This may be due to the fact that many of the students didn’t miss time over this particular three week unit so the benefit didn’t stick out to them. Students may have also come to the conclusion that although they were still able to get a basic level of content understanding while absent, they still missed a valuable part of the learning by not being able to discuss and work with peers in class. Before watching a video, 48% of students believed the ability to watch, pause, and rewind instructional videos to learn at their own pace would benefit their learning. This number rose to 60% by the culmination of the unit, apparently benefiting both the weaker and the stronger students. As one student wrote, “I could rewind when I didn’t understand something the first time.” On the other hand, a different student put it this way, “I like learning the lessons at my own speed without having to stop for the teacher to answer other students' questions.”

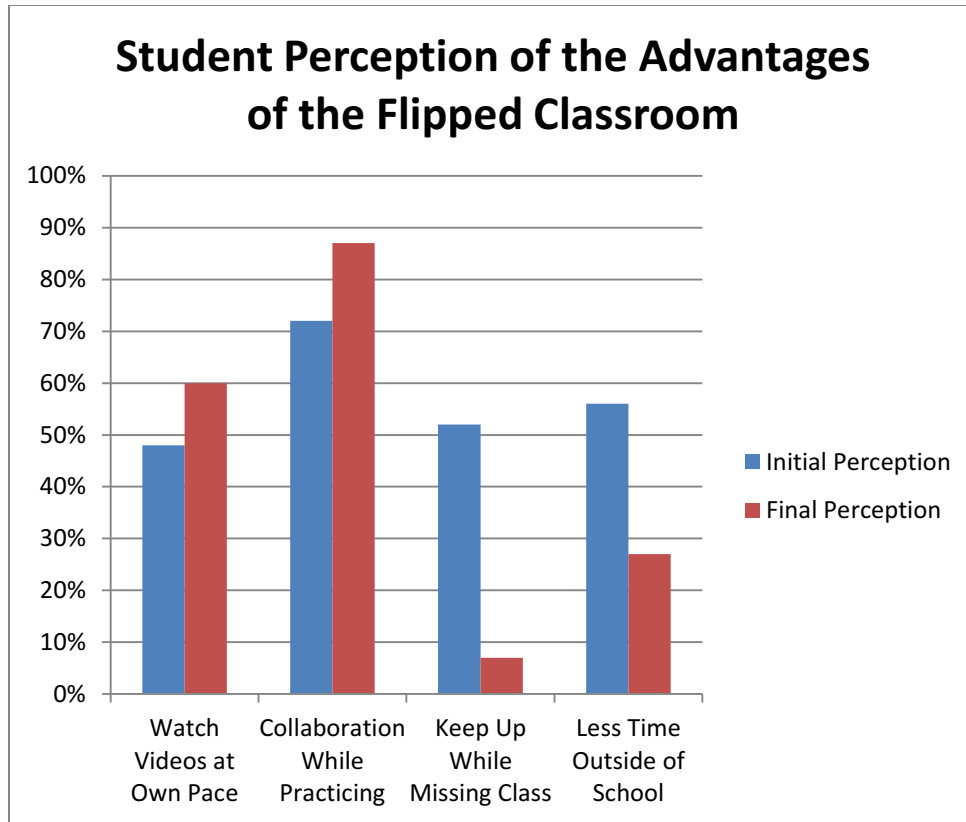


Figure 3-7: Students perception of the advantages the flipped classroom changed after experience

Students were also surveyed to determine their perception of the biggest disadvantages of learning in a flipped classroom. In the initial survey, 78% of students were concerned about not being able to ask the teacher face-to-face questions during instruction. This number rose slightly to 82% by the final survey (Figure 3-8). Before watching any of the videos, 65% of students were unsure if the learning would be as engaging because it was done through a video, but that concern appeared to fade as they became used to the instructional style. If all subjects begin to shift to this way of learning, students may become inundated if the videos aren't kept short. Initially 43% of students thought they may fall behind as they thought they wouldn't watch all the videos either as a matter of choice or because they wouldn't have time; by the end, this opinion

was reported by 20% of students. A thoughtful student wrote, “The flipped classroom puts more stress and responsibility on the student because they are required to watch and understand the videos which can be difficult when you have more than one flipped classroom and/or after school activities.” A small number of students thought that working on practice problems in the classroom would be an issue as they find themselves more easily distracted in the classroom than at home. A couple of students did mention the concern that their internet access might be unreliable and that their access to the videos might be limited.

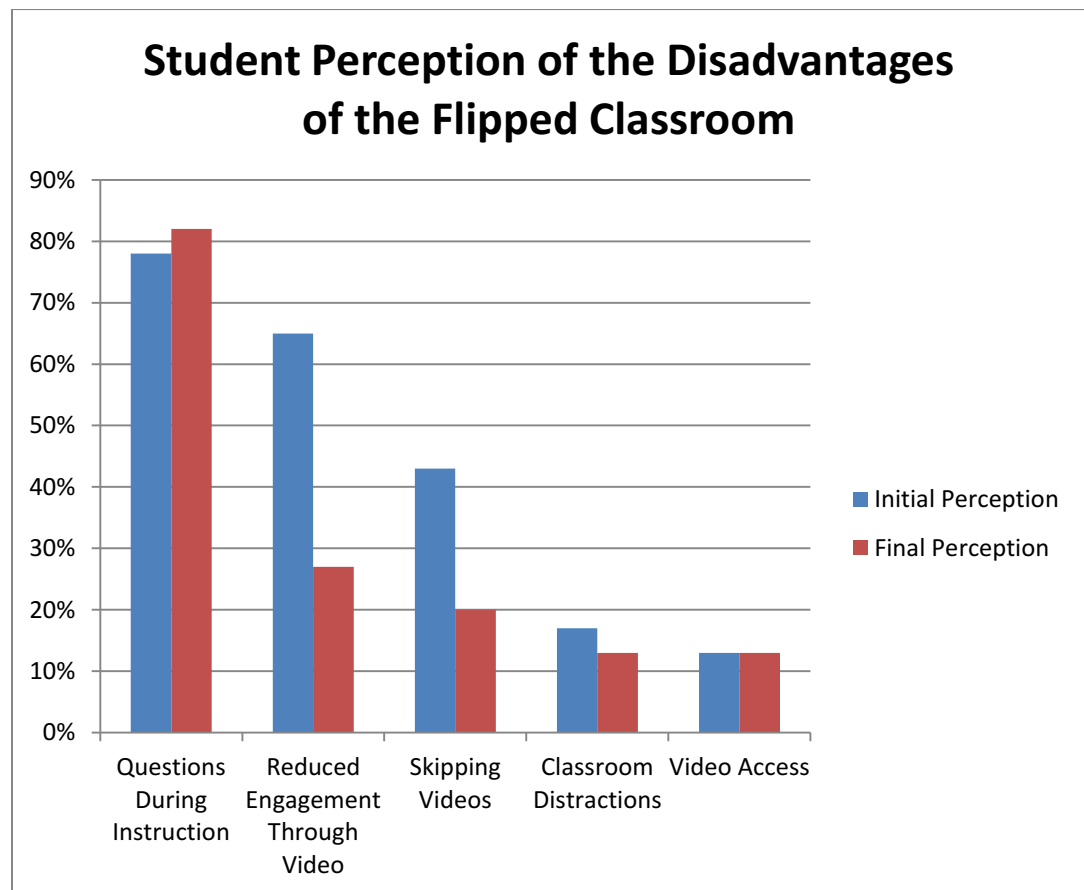


Figure 3-8: Students perception of the flipped classroom’s disadvantages changed after experience

The largest concern appears to be that students appreciate the convenience, safety and security of being able to ask questions as they arise. As one student wrote, “The biggest downside was not having real people able to help me when learning at home. Instead I was relying on myself for all clarification.” Although a teacher could argue that the student would feel the same way while solving the homework problems, it would be beneficial for students to have a way for their questions outside of class to be answered. Teachers can implement a system where all students must come prepared for class’s opening discussion with at least one question on the previous night’s video. Not only would students feel more comfortable generating questions if they know everyone else is doing it as well, but it would allow for a more effective discussion which targets the more confusing topics of the content. Teachers can also help reduce the fear by allowing and encourage comments and questions on the videos. Teachers can also encourage students to email them the moment a question arises so the teacher can either respond the same evening or choose to address it at the start of the following class.

After the initial presentation, 54% of students anticipated that the traditional model would be more conducive to learning and understanding math concepts best; just 8% thought that the flipped classroom model would be the more effective model (Figure 3-9). The remaining 38% thought either model would be satisfactory and their learning would be the same regardless of the instructional selection.

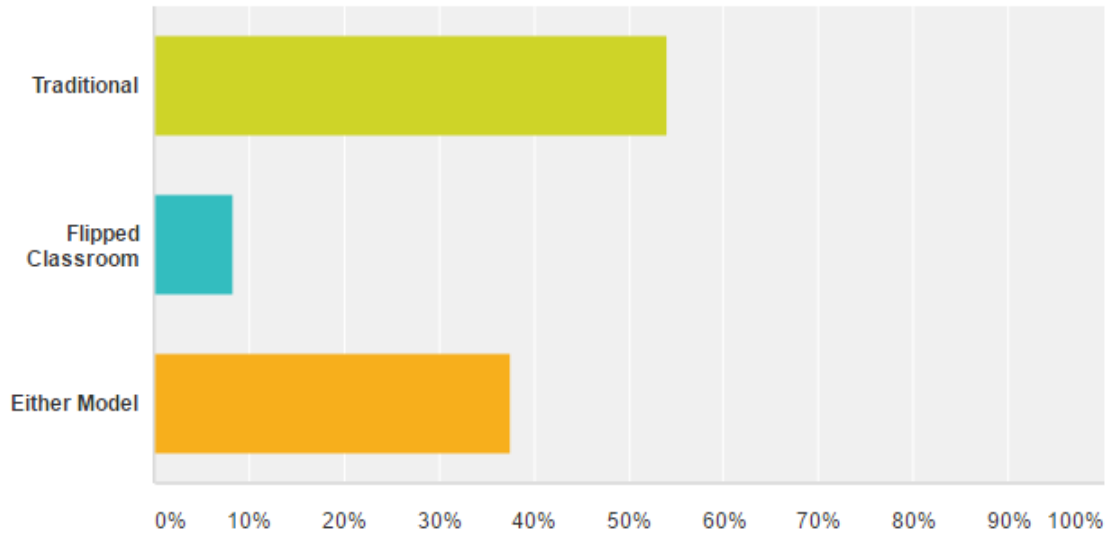


Figure 3-9: Initial results of which instructional model students perceive would help them learn and understand math concepts best

After the final unit test, 60% of students believed the traditional model would be more conducive to learning and understanding math, while 20% of students believed the flipped classroom model was more effective (Figure 3-10). The remaining 20% believed both models were equally effective. Compared to the original survey, the number of students who preferred the traditional model increased very slightly whereas about half of the students who originally thought either model would work equally well for them picked one side or the other. This raised the number of students who thought that a flipped classroom would be more effective. Overall, it appears as though the majority of students in this study believed that the flipped classroom was not as effective as the traditional model.

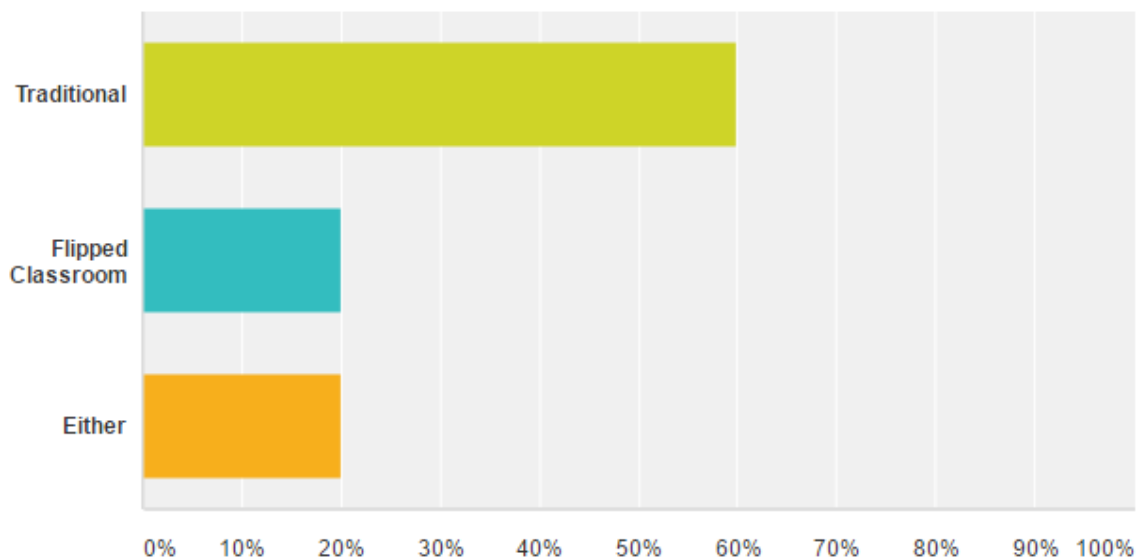


Figure 3-10: Final results of which instructional model students perceive would help them learn and understand math concepts best

Student engagement in math activities inside (Figure 3-11) and outside the classroom (Figure 3-12) was relatively balanced. Respondents slightly favored the engagement of the traditional classroom. Some students reported favoring the traditional classroom because, as one student wrote, “It is easy to get distracted while working on practice problems with friends.” Moreover, some students reported favoring the traditional way of doing homework because it is, “more hands-on to solve a problem than to watch a video.” When students were asked about how they believed their own perception had changed, there were mixed results. 50% of the students reported no change in perception and 28% of students reported liking the flipped classroom more than they had originally anticipated (Figure 3-13).

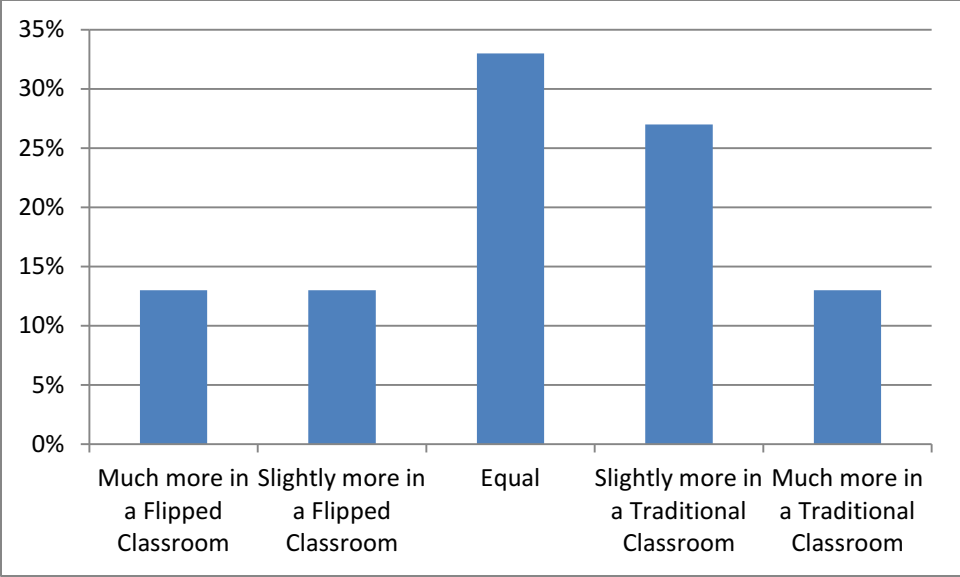


Figure 3-11: Engagement in Math Activities Inside the Classroom

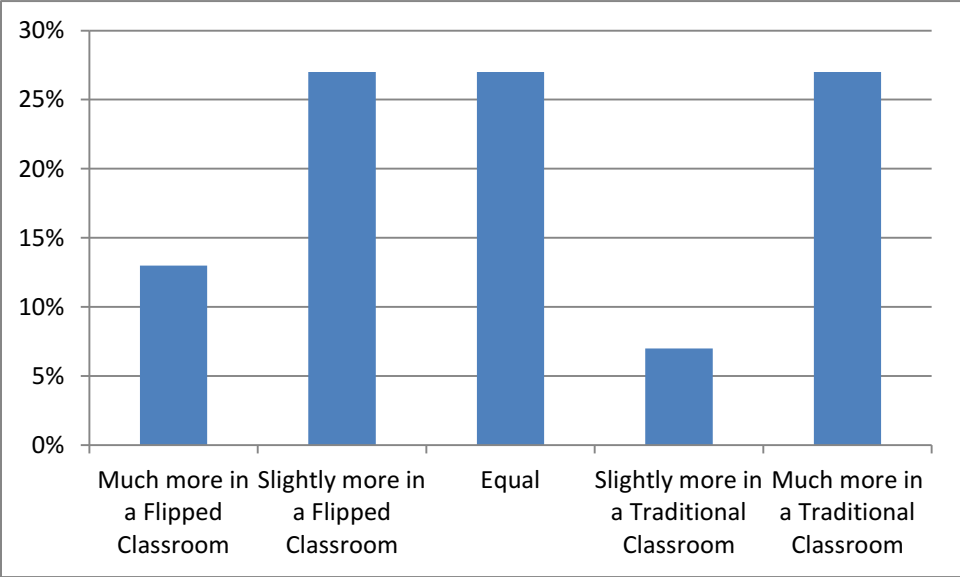


Figure 3-12: Engagement in Math Activities Outside the Classroom

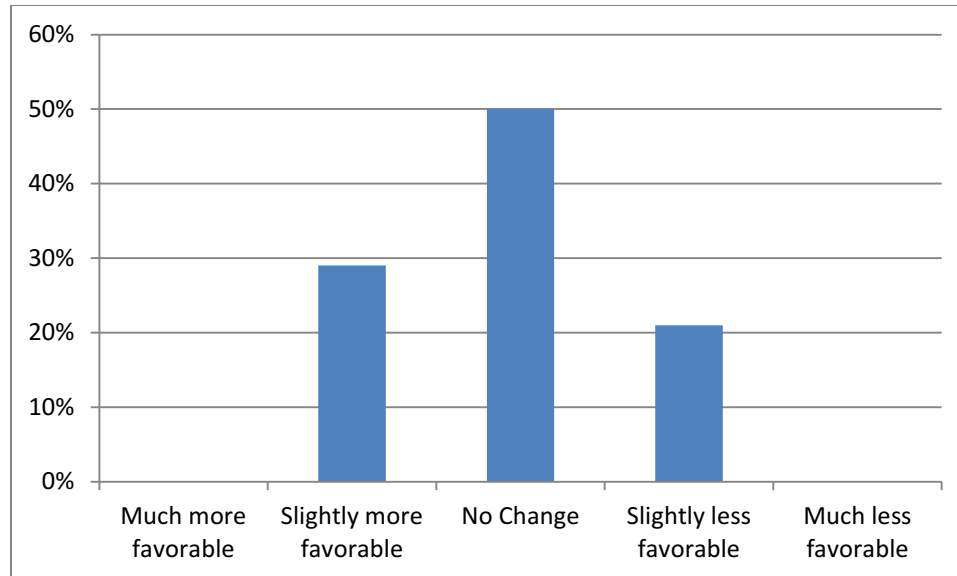


Figure 3-13: Change in Student Opinions Towards the Flipped Classroom

One of the last items on the third survey asked students to reflect on their experience and offer advice for a student whose teacher was flipping the classroom. 80% of the responses reiterate urging the fellow students to actually complete the work asked of them. A few of the responses were selected and are presented below. Together they sum up the experiences of the students in a flipped classroom:

“Actually watch the videos and do the work before you come into class, or you'll be very confused and behind.”

“If you don't write down a question, you might forget it by class.”

“Pay attention in class when the teacher is going over the video's content from the previous night.”

“Take advantage of the practice in class and be sure to ask the teacher questions when you do not know how to get started on an exercise.”

Teacher Perception and Reflection on First Flip

The following subjective reflection is a four-part, first-hand account of the various stages of the process of flipping the classroom the first time. One component of this process is the set of challenges associated with video creation and development. A second component is my perception of the students' reactions to the initial introduction of the flipped classroom experiment. I was interested in how they would respond to the idea as well as the logistics and expectations I had for the students on how to watch videos at home. A third component is my perception of the students' engagement during in-class activities. The final component is an anecdotal comparison of the flipped classroom students' scores to the historical scores on the same assessment.

When I first dreamed of flipping my classroom, I believed that creating the videos would be the easy part. After all, I was bringing a considerable amount of experience to the table, and would be able to incorporate visual effects to help elucidate the points I was making on video. I was under the impression that by creating an outstanding video, the in-class portion would be easy as the questions would be few and far between – that students would understand what I was teaching more clearly than if I simply filmed myself teaching the lesson.

While I was able to put together a couple videos of the quality I was hoping, I realized that not only did they take a considerable amount of time, but students still had questions after they watched the video. I realized that I couldn't create the perfect video and that the recorded lessons simply gave the students initial exposure to low-level acquisition of the material. There was still a need to review the key concepts from the

video at the start of class and allow time for the students to ask their individual questions as they worked on an in-class activity.

When I initially presented the idea of a flipped classroom to my students, they did not appear either as excited or as upset as I imagined they might be. There were questions about the video style and if I would “still make my funny side comments, jokes, and analogies” during the videos. They mentioned that they didn’t mind the quality of the videos if I was the one teaching, which was a profound realization for me. I realized that the relationship we had built mattered when it came to having the students buy into watching the videos. The quality of the videos mattered less than the content because they knew who I was. I theorize that the students would be less likely to be engaged by a poor quality video if they didn’t have a personal connection to the person in the video.

In terms of using PlayPosit for video bulbs with interactive questions, I still really like the idea, in theory, of pausing the videos automatically and asking questions. This website runs well on the computer. However most of my students watched the videos on their phones. Each morning, students would come in and say that the video stopped for them and wouldn’t keep playing and that there wasn’t an option for them to click to continue. While I never replicated this glitch personally, there were many students who mentioned the error. Consequently, I decided that the next time I flip the classroom I will instead simply include verbal prompts for them to manually pause the video to try a particular problem.

When students chose not to watch the videos at home, they were required to watch with headphones during class. Unfortunately, these students quickly fell behind

their peers as they did not have the same amount of practice, peer discussion, or time to ask the teacher questions. While this issue still remains a huge barrier to learning, students who chose not to do their homework in a traditional classroom fall behind as well as they do not receive the same practice as other students. In either instructional model, students who do not participate in the activities outside of the class period will inherently face more barriers to success than their peers who complete what is assigned to them to do outside of class.

After the final unit test was graded and returned, I was curious to see how the students this year compared to the students on the same assessment the previous year. The students who had been taught using the flipped classroom averaged an 87.14% on the unit test, while the students who had been taught using the traditional classroom the year before averaged an 80.67%. When looking at the difference in those numbers it is important to note that this study was not designed to test the effectiveness of the flipped classroom versus the traditional classroom. Although the instructor and the assessment remained the same, there were a number of other variables that could lead to an improvement, such as the teacher being more familiar with common student mistakes, or the mathematical backgrounds and study habits of students involved being better. The improvement in scores in the flipped classroom (and therefore, presumably, the increased understanding) cannot be directly attributed to the change in teaching style without further research. However, the results could be encouraging to teachers who wish explore this style of teaching as math understanding may improve.

Chapter IV.

Summary and Conclusions

Jon Bergman and Aaron Sams first experimented with the idea of Flipping the Classroom in 2007, and the instructional methodology in support of the flipped classroom has since grown considerably in the educational community. Proponents describe many benefits to the inversion of traditional teaching methods whereby basic content is delivered through instructional videos and homework completion is moved into the classroom. This not only allows students to watch and re-watch lectures at their own pace, but also gives the students a chance to collaborate with the teacher and their peers on the more challenging homework questions in class.

The flipped classroom is something that teachers can try for a lesson or a unit before changing their entire course. In preparation for a flip, teachers will likely spend more time before the lesson than they would for a traditional lesson because of the time required to develop or select video material and in-class activities. When preparing instructional videos, teachers should keep in mind that the runtime should be no more than 10 to 15 minutes for high school students, and that embedded questions can double the time it takes to view them. Students appreciate when the videos are created by their own teacher and are willing to tolerate a lower quality video as long as it features their familiar teacher. Teachers should also consider the option of repurposing other high-quality publicly available material. This can help reduce the initial time requirement. Teachers should not get caught up in finding a perfect video as a successful flip depends much more on what the educator is able to do during the corresponding class time.

When initially presenting the flip to the students, teachers should spend a class session describing what a flipped classroom is, and what its primary benefits are. The three advantages of most interest to students that 1) they will always have access to recorded instructional videos and can learn at their own pace, 2) students are able to get immediate support in-class from peers and get individual attention from the teacher when they have questions on practice problems, and 3) the flipped classroom is a much more active way to learn which has the potential to improve their understanding of the material and their performance.

During the first class session, teachers should also set a few clear expectations regarding the class culture. First, teachers should spend some time explaining how they expect the students to actively take notes and watch videos otherwise students may revert to the natural passive process of watching a movie. Second, teachers need to have a plan and articulate what students should do when they have a question at home. This can be as simple as having all students write down questions to guide the next day's in-class discussion, or by implementing a way for students to submit questions electronically through a discussion board, or via email. Third, teachers need to tell students how to interact with the teacher and with their peers during in-class activities as these are the most important learning activities. Lastly, it is imperative that teachers emphasize the importance of responsibly watching the videos before class time, as students will only be able to and only be allowed to participate if they are prepared, otherwise they must watch the video during the class period which would prevent them from participating in the enriching class activity. To help students without home access to internet, or students

who have unforeseen technology issues on a particular night, teachers can inform students about ways to take advantage of a school computer.

Teachers should expect that not all students will like the flipped classroom because sitting through a lecture is familiar, comfortable, and easy as it requires very little effort on their part. When this is changed, students realize that being responsible for their own learning can be hard and therefore not every student is going to like the flipped classroom. Teachers should keep reminding students of the benefits and keep working to help students take responsibility for their own learning.

With a variety of companies creating a repository of videos and activities for the flipped classroom, it is getting easier for teachers to try the technique. As the flipped classroom is implemented more frequently, further empirical evidence is needed to determine whether it is a more effective instructional technique than traditional lecture, although effectiveness could be defined in a variety of ways. Effectiveness could mean student happiness and engagement, improvement in assessment scores, attitude towards homework, or how well students develop as independent learners.

Future work in investigating objective learning outcomes should include a control group to measure the effectiveness of the instructional technique. This work could also extend to the study of long term knowledge retention by comparing results on an identical assessment. Do students who have a more interactive classroom experience through the flipped classroom retain math better after being removed from the instruction for a period of time, perhaps as much as six months to a year?

With more software, like PlayPosit, allowing teachers to embed interactive questions into their videos, another study could look closely at the effectiveness of the

interactive, embedded videos. Educators may determine how much of an impact these questions have on knowledge acquisition. Researchers studying flipped classrooms could create a control group of students whose videos did not have embedded questions and a second group of students whose videos included the embedded questions and see how the two groups perform on identical assignments.

Finally, further research could be performed trying to identify the most effective activities in the classroom. According to Bishop and Verleger's research, students typically prefer classroom time to be spent on interactive, hands-on activities (2013). What types of classroom activities are most effective? For example, researchers could explore project-based learning, inquiry labs, or virtual learning communities in conjunction with the flipped classroom.

On a personal note, I am encouraged by my students' results and by my perception of their level of engagement during in-class activities over the course of this Precalculus unit, and I intend to flip the classroom for my Precalculus classes throughout the next school year. I believe I am more prepared, the second time around, for presenting on the first day of class, both the benefits of the flipped classroom and the associated demands on the students. I anticipate that my enthusiasm for the flipped classroom's potential will inspire my students for an even more successful year.

Appendix 1.

Survey of Precalculus Study Habits

The survey below was administered using the online service SurveyMonkey. Survey items without choices listed required a typed in response.

1. In math class, how frequently:

	Always	Often	Sometimes	Rarely
Do you take notes?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Do you publicly ask clarification questions when teaching is unclear?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Do you pay 100% attention to the instruction without distractions?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Do teacher/classmates work through problems on the board too quickly for you to follow?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. On an average school night, how much time do you spend on all homework?

- Less than 1 hour
- 1 to 2 hours
- 2 to 3 hours
- 3 to 4 hours
- More than 4 hours

3. How many minutes per night do you spend on math homework on average when it is assigned?

- Less than 20 minutes
- 20 to 40 minutes
- 40 minutes to 60 minutes
- 60 minutes to 90 minutes
- More than 90 minutes

4. If you were given math homework on 10 consecutive days, how many assignments would you fully complete?
- 10
 - 9
 - 8
 - 7
 - 6 or less
5. How valuable to your understanding do you perceive the completion of math homework?
- Always valuable
 - Often valuable
 - Sometimes valuable
 - Rarely valuable
 - Never valuable
6. On a given night, what percent of the assigned math homework questions can you complete without assistance from the teacher or a friend?
- Less than 60%
 - 60% to 70%
 - 70% to 80%
 - 80% to 90%
 - 90% to 100%
7. On an average night, how many assigned math homework questions do you make sure you've correctly completed by checking in the back of the book or with a friend?
- 0 to 25%
 - 25% to 50%
 - 50% to 75%
 - 75% to 100%

8. How often do you use additional videos or websites at home for extra help or to support your learning?

- Always
- Often
- Sometimes
- Rarely
- Never

Appendix 2.

Survey of Initial Perception of the Flipped Classroom

The survey below was administered using the online service SurveyMonkey. Survey items without choices listed required a typed in response.

1. Please rate how helpful each of the listed benefits of learning in a flipped classroom will be to you:

	Always	Often	Somewhat	Rarely
The ability to watch, pause, and rewind instructional videos to learn at your own pace	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Teacher and peers are available for collaboration while practicing and applying new knowledge.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Missing class no longer prohibits you from learning the day's material.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Watching videos instead of completing homework should take less time outside of school.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. Apart from those listed in question 1, are there any other reasons you think the flipped classroom may help you learn better?

3. Which of the following drawbacks of learning in a flipped classroom do you think will make learning more difficult for you (check all that apply)?
- You have limited access to the internet/videos outside of class.
 - You find yourself easily distracted by friends, peers, or technology in the classroom.
 - You think you may choose to not watch some of the instructional videos outside of class.
 - You are not able to ask the teacher face-to-face questions during instruction.
 - Learning may be less engaging because some educational videos can be boring.
4. Are there any other reasons the flipped classroom may make it more difficult to learn?
5. Comparing the Traditional model of instruction (instruction in-class, practice outside of class) and the flipped classroom model (practice in-class, instruction outside of class): If given the choice, through which model do you feel you would learn and understand math concepts BEST?
- Traditional
 - Flipped Classroom
 - Either Model
6. When you watch the instructional videos, you think you will (check all that apply):
- Take notes on the provided guided notes
 - Re-watch sections when you do not understand a concept
 - Mark when you have questions in the notes
 - Pay 100% attention to the video with no distractions
 - Enjoy the interactive questions built in to the videos

Appendix 3.

Survey of Final Perception of the Flipped Classroom

The survey below was administered using the online service SurveyMonkey. Survey items without choices listed required a typed in response.

1. How many of the videos did you watch during the unit?
 - None
 - 1 or 2
 - A few
 - All but 1 or 2
 - All that were assigned

2. When you watched the instructional videos, did you (check all that apply):
 - Take notes on the provided guided notes
 - Re-watch sections when you do not understand a concept
 - Mark when you have questions in the notes
 - Pay 100% attention to the video with no distractions
 - Enjoy the interactive questions built in to the videos

3. On average, how many minutes did you spend watching the math instructional videos or doing assigned math work over this unit?
 - Less than 10 minutes
 - 10 to 20 minutes
 - 20 to 30 minutes
 - 30 to 40 minutes
 - More than 40 minutes

4. I found it helpful to do practice questions when other students and the teacher are available to answer questions as opposed to doing the homework exercises by myself.
- Always
 - Often
 - Sometimes
 - Rarely
 - Never

5. Rate your engagement in math activities:

	Much more in a flipped classroom	Slightly more in a flipped classroom	Equal in both a flipped or traditional classroom	Slightly more in a traditional classroom	Much more in a traditional classroom
During the class period?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
At home outside the class?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

6. Now that you've experienced a flipped classroom unit, what do you perceive to be the advantages to you as a learner?
7. What do you perceive to be the disadvantages of the flipped classroom to you as a learner?
8. How has your initial perception of the flipped classroom changed from when it was initially introduced?
9. What advice would you give to another student whose math teacher was going to use the flipped classroom model?

10. You've now experienced a Traditional model of instruction (instruction in-class, practice outside of class) and the flipped classroom model (practice in-class, instruction outside of class): If given the choice, through which model do you feel you would learn and understand math concepts BEST?

- Traditional
- Flipped Classroom
- Either Model

Appendix 4.

Flipped Classroom Unit Plan Outline

Day 1	Day 2	Day 3	Day 4	Day 5
In-Class: <ul style="list-style-type: none"> • Flipped Classroom Overview • Groups of 2-3: Trigonometry Gallery Walk 	In-Class: <ul style="list-style-type: none"> • Solving Right Triangles with SOH-CAH-TOA 	In-Class: <ul style="list-style-type: none"> • Trigonometry Word Problems 	In-Class: <ul style="list-style-type: none"> • Trigonometry Word Problems with Headings and Bearings 	In-Class: <ul style="list-style-type: none"> • Solving Special Right Triangles
After Class: <ul style="list-style-type: none"> • Video: Solving Right Triangles with SOH-CAH-TOA 	After Class: <ul style="list-style-type: none"> • Video: Trigonometry Word Problems (Eiffel Tower and Shark Distance) 	After Class: <ul style="list-style-type: none"> • Video: Headings and Bearings 	After Class: <ul style="list-style-type: none"> • Video: Special Right Triangles 	After Class: <ul style="list-style-type: none"> • Video: Radians and Degrees • Video: Negative Angles and Coterminal Angles • Article: Why Radians, Not Degrees
Day 6	Day 7	Day 8	Day 9	Day 10
In-Class: <ul style="list-style-type: none"> • Converting from Degrees to Radians, Arc Length, and Finding Coterminal Angles 	In-Class: <ul style="list-style-type: none"> • Groups: Online Unit Circle Game • Trig Practice Using the Unit Circle 	In-Class: <ul style="list-style-type: none"> • Trigonometry Whiteboard Game 	In-Class: <ul style="list-style-type: none"> • Trig Functions of Any Angle 	In-Class: <ul style="list-style-type: none"> • Assorted Trig Review Problems
After Class: <ul style="list-style-type: none"> • Video: Coordinates on the Unit Circle • Video: Evaluating Trig Functions using the Unit Circle (Ref. Angles, All Students Take Calc.) 	After Class: <ul style="list-style-type: none"> • Video: Definitions of Trig Functions and Properties 	After Class: <ul style="list-style-type: none"> • Video: Trig Functions of Any Angle (angles not on the unit circle) 	After Class: <ul style="list-style-type: none"> • Video: Pythagorean Identities 	After Class: <ul style="list-style-type: none"> • Prepare for Quiz Tomorrow • 4.1-4.4 Review Problems due by the end of class on Wednesday
Day 11	Day 12	Day 13	Day 14	Day 15
In-Class:	In-Class:	In-Class:	In-Class:	In-Class:

<ul style="list-style-type: none"> • Quiz 4.1-4.3 	<ul style="list-style-type: none"> • Amplitude and Period Practice 	<ul style="list-style-type: none"> • Phase Shifts 	<ul style="list-style-type: none"> • 4.1-4.4 Review Problems 	<ul style="list-style-type: none"> • Chapter 4.1-4.4 Test
<p>After Class:</p> <ul style="list-style-type: none"> • Graphs of Sine, Cosine, and Tangent 	<p>After Class:</p> <ul style="list-style-type: none"> • Video: Phase Shifts 	<p>After Class:</p> <ul style="list-style-type: none"> • Study for Upcoming Test 	<p>After Class:</p> <ul style="list-style-type: none"> • Study for Test Tomorrow 	<p>After Class:</p> <ul style="list-style-type: none"> • Reflection on Flipped Classroom

References

- Amos, A. (2012, October 1). STEM teacher uses 'flip' method to put classroom focus on students, not educator. *The Knoxville News Sentinel*, p. D1
- Armstrong, P. (2013). Bloom's Taxonomy. Retrieved November 7, 2015, from <https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/>
- Ash, K. (2012, September 12). Educators evaluate 'flipped classrooms' Retrieved January 6, 2016, from <http://www.edweek.org/ew/articles/2012/08/29/02elflipped.h32.html>
- Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day*. Eugene, Or: International Society for Technology in Education.
- Bergmann, J., & Sams, A. (2015). *Flipped learning for math instruction*. International Society for Technology in Education.
- Berrett, D. (2012, February 19). How 'flipping' the classroom can improve the traditional lecture. *The Chronicle of Higher Education*.
- Bishop, J. L., & Verleger, M. A. (2013). *The flipped classroom: A survey of the research* (6219). Atlanta, Georgia: ASEE National Conference Proceedings.
- Brame, C. J. (2013). Flipping the Classroom. Retrieved November 7, 2015, from <https://cft.vanderbilt.edu/guides-sub-pages/flipping-the-classroom/>
- Clintondale High School. (2013). About Clintondale High School. Retrieved January 13, 2016, from <http://flippedhighschool.com/>
- Covey, S. R. (2004). *The 7 habits of highly effective people: Restoring the character ethic*. New York: Free Press.
- Digest of American Statistics. (2011). *Average daily attendance (ADA) as a percentage of total enrollment, school day length, and school year length in public schools, by school level and state: 2003-04 and 2007-08*. Retrieved from https://nces.ed.gov/programs/digest/d11/tables/dt11_043.asp
- Edudemic. (2016). The Teacher's Guide to: Flipped Classrooms. Retrieved from <http://www.edudemic.com/guides/flipped-classrooms-guide/>
- Engelbrecht, T. (2014, February 17). Educanon: Flipping made easy [Web log post]. Retrieved from <http://www.crazyteacherlady.com/crazy-thoughts/educanon-flipping-made-easy>

- File, T., & Ryan, C. (2014). *Computer and internet use in the United States: 2013*. Retrieved from American Community Survey Reports website: <https://www.census.gov/history/pdf/2013comp-internet.pdf>
- Flipped Institute. (2012). How to flip the classroom. Retrieved from <http://flippedinstitute.org/how-to-flip>
- Flipped Learning Network. (2012). Improve student learning and teacher satisfaction with one flip of the classroom. Retrieved from <http://www.flippedlearning.org/cms/lib07/VA01923112/Centricity/Domain/41/classroomwindowinfographic7-12.pdf>
- Feyzioglu, E. (2012). Science teachers' beliefs as barriers to implementation of constructivist-based education reform. *Journal of Baltic Science Education*, 11(4), 302-317.
- Fulton, K. (2012). Inside the flipped classroom. *The Journal*. Retrieved from <http://thejournal.com/Articles/2012/04/11/The-flipped-classroom.aspx>.
- Hamdan, N., McKnight, P., McKnight, K., & Arfstrom, K. (2013). *A review of flipped learning*. Retrieved from Flipped Learning Network website: <http://www.flippedlearning.org/review>
- Hunley, R. (2016). *Teacher and student perceptions on high school science flipped classrooms: educational breakthrough or media hype?* (Doctoral dissertation). Retrieved from <http://dc.etsu.edu/etd/3052>
- Johnson, G. B. (2013). *Student perceptions of the flipped classroom* (Master's thesis, University of British Columbia, Vancouver, Canada). Retrieved from <https://open.library.ubc.ca/cIRcle/collections/ubctheses/24/items/1.0073641>
- Karabulut-Ilgu, A., Jaramillo Cherez, N. and Jahren, C. T. (2017), A systematic review of research on the flipped learning method in engineering education. *British Journal of Educational Technology*. doi: 10.1111/bjet.12548
- Kirch, C. (2012, July 19). Flipping with kirch: Introducing the flipped class to students [Web log post]. Retrieved from <http://flippingwithkirch.blogspot.com/2012/07/introducing-flipped-class-to-students.html>.
- Madden, M., Lenhart, A., Duggan, M., Cortesi, S., & Gasser, U. (2013, March 12). *Teens and Technology 2013*. Retrieved August 26, 2017, from <http://www.pewinternet.org/2013/03/13/teens-and-technology-2013/>.
- McInerney, D. M. (2014). *Educational psychology: constructing learning*. Frenchs Forest, N.S.W.: Pearson Australia Group.

- Nemerow, D. (2015, March 13). The flipped classroom: one teacher's reflections on an innovative idea. Retrieved from <http://flippedclass.com/newsroom/recent-coverage/the-flipped-classroom-one-teachers-reflections-on-an-innovative-idea/>
- O'Malley, M. (2015). *Constructivism: the effects of the flipped classroom instructional model on high school senior ap biology students* (Master's thesis, Montana State University, Bozeman, Montana). Retrieved from <http://scholarworks.montana.edu/xmlui/handle/1/9285>
- Overmyer, G. R. (2014). *The flipped classroom model for college algebra: Effects on student achievement* (Doctoral dissertation). Retrieved from <http://hdl.handle.net/10217/83800>
- Panopto. (2015, August 31). Preparing to flip a classroom? Here's what to plan for [Web log post]. Retrieved from <http://panopto.com/blog/preparing-to-flip-a-classroom-heres-what-to-plan-for/>
- Pearson, P., & Gallagher, M. (1983). The instruction of reading comprehension. *Contemporary Educational Psychology*, 8(3), 317-344. [http://dx.doi.org/10.1016/0361-476x\(83\)90019-x](http://dx.doi.org/10.1016/0361-476x(83)90019-x)
- Perrin, A., & Duggin, M. (2015, June 26). Americans' internet access: 2000-2015. Retrieved January 13, 2016, from <http://www.pewinternet.org/2015/06/26/americans-internet-access-2000-2015/>
- Protheroe, N. (2007). "What Does Good Math Instruction Look Like?" *Principal* 7(1), pp. 51 – 54.
- Project Tomorrow. (2015). *Project Tomorrow and The Flipped Learning Network Speak Up 2014 National Data*. Retrieved from http://www.tomorrow.org/speakup/2015_FlippedLearningReport.html
- Raths, D. (2013, November). 9 video tips for a better flipped classroom. *THE Journal*, 40(11), 12-18.
- Skinner, B. (1958). Teaching Machines: From the experimental study of learning come devices which arrange optimal conditions for self-instruction. *Science*, 128(3330), 969-977.
- Sophia. (2015). Growth in Flipped Learning. Retrieved December 10, 2015, from <https://www.sophia.org/flipped-classroom-survey>
- Weegar, M., & Pacis, D. (2012). A Comparison of two theories of learning –behaviorism and constructivism as applied to face-to-face and online learning. E-Leader Manila 2012. Retrieved August 4, 2017 from <http://www.g-casa.com/conferences/manila/papers/Weegar.pdf>