DISSERTATION

THE FLIPPED CLASSROOM MODEL FOR COLLEGE ALGEBRA: EFFECTS ON

STUDENT ACHIEVEMENT

Submitted by

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ABSTRACT

THE FLIPPED CLASSROOM MODEL FOR COLLEGE ALGEBRA: EFFECTS ON

STUDENT ACHIEVEMENT

In the past few years there has been a substantial rise in the use and interest in a teaching and learning paradigm most commonly known as the flipped classroom. The flipped classroom model encompasses any use of using Internet technology to leverage the learning in a classroom, so that a teacher can spend more time interacting with students instead of lecturing. This is most commonly done by using teacher created videos that students view outside of class time. It is called the flipped class model because the whole classroom/homework paradigm is "flipped". In its simplest terms, what used to be classwork (the lecture) is done at home via teacher-created videos and what used to be homework (assigned problems) is now done in class. Five sections of college algebra where taught using the flipped classroom model. Six sections of college algebra where taught using the traditional method of lecture and homework.

This quasi-experimental quantitative research compares sections of college algebra using the flipped classroom methods and the traditional lecture/homework structure and its effect on student achievement as measured through common assessments. In the traditional sections, students spent class time receiving lecture and reviewing homework and exams. Outside class time was spent on traditional homework. In the flipped sections, students viewed short video lectures and submitted basic homework solutions online outside of class time. Students then completed their homework assignments in class with the instructor. Some flipped section instructors also used collaborative group work, inquiry-based learning, and active whole-class

discussions. All sections took common assessments for their final exam and completed a pre/post algebra readiness exam.

The exam data from the sections were analyzed and compared using regression and ANOVA methods with instructional method, gender, and ACT mathematics scores as independent variables. Final exam scores and pre/post algebra readiness exam scores were the dependent variables. The findings of this research show that there was not a statistically significant difference in the scores of student in the two groups, however students in the flipped sections did score slightly better than student in the traditional sections. Instructors of flipped sections who had previous classroom experience with inquiry-based and cooperative learning methods had sections with statistically significant higher common final exam scores. The results are followed by implications for teaching and recommendations for practice and further research.

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CHAPTER 1

INTRODUCTION

Recently, a paradigm shift has taken place in education with the advent of a model of teaching known as the flipped classroom. The flipped classroom model encompasses any use of using Internet technology to leverage the learning in a classroom, so that a teacher can spend more time interacting with students instead of lecturing (Bergmann & Sams, 2012a). This is most commonly being done using teacher-created videos that students view outside of class time. It is called the flipped class model because the whole classroom/homework paradigm is "flipped". In its simplest terms, what used to be classwork (the lecture) is done at home via teacher-created videos and what used to be homework (assigned problems) is now done in class.

With the proliferation of Internet technology, virtual communications, and learning management systems, many college and university instructors are interested in a flipped classroom (Berrett, 2012). This research compares the flipped classroom model with traditional lecture courses in college algebra. In the flipped class sections, teachers create online videos of their lectures, having students view them and take notes before attending class. Students then work in class on inquiry-based assignments, which includes what is traditionally thought of as homework. This creates the flipped classroom, thus completely shifting the paradigm of teaching and learning.

Brief History of the Flipped Classroom Model

Students raised on new media technologies are less patient with filling out worksheets and listening to lectures (Collins & Halverson, 2009). Technology has reached a level where the time is now for true educational reform that increases student content achievement while

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teaching important 21st century skills. Progressive teachers and administrators must understand the reality and the pervasiveness of information technology in the lives of students. A Time magazine article, "How to Bring Our Schools out of the 20th Century" commented:

American schools aren't exactly frozen in time, but considering the pace of change in other areas of life, our public schools tend to feel like throwbacks. Kids spend much of the day as their great-grandparents once did: sitting in rows, listening to teachers lecture, scribbling notes by hand, reading from textbooks that are out of date by the time they are printed. A yawning chasm (with an emphasis on yawning) separates the world inside the schoolhouse from the world outside. (Wallis & Steptoe, 2006, p. 2)

With advances in Internet and communications technology, it is becoming easier for teachers to offer dynamic multi-media educational resources and the capability to support both content and assessment between instructors and learners. Cloud computing and services such as YouTube, Teacher Tube, and Screencast.com make the sharing of video resources increasing accessible for all teachers and students. Technology educators predict that within a few years, tablet PCs, laptop computers or smartphones with wireless Internet will be carried by nearly all students (Levy, 2010).

The current method of using online videos to flip learning was developed by Jonathan Bergmann and Aaron Sams in Woodland Park, Colorado in 2007 (Bergmann, 2011). Bergmann and Sams were looking for a way to provide lectures to their students who missed classes due to travel for athletics or activities. Jon Bergmann recalls:

In the spring of 2007 Aaron was thumbing through a technology magazine and showed me an article about some software that would record a PowerPoint slideshow including voice and any annotations, and then it converted the recording into a video file that could

be easily distributed online. As we discussed the potential of such software we realized this might be a way for our students who missed class to not miss out on learning. Thus, we began to record our live lessons using screen capture software. We posted our lectures online so our students could access them. When we did this, YouTube was just getting started and the world of online video was just in its infancy. In all honesty, we recorded our lessons out of selfishness. We were spending inordinate amounts of time re-teaching lessons to students who missed class, and the recorded lectures became our first line of defense. (p.1)

This has created a new perspective in education. In early 2010, a professional learning network was created for educators interested in the flipped model. As of May, 2013, the network has over 16,000 members worldwide (Overmyer, 2013). This network provides both pedagogical and best-practice discussions, as well as pragmatic support on technology and implementation. However, empirical research is just starting to be conducted to establish if any of the claims are actually supported with higher student achievement.

Characteristics of the Flipped Classroom

Though no two flipped classrooms look the same, they all share common characteristics, as articulated in The Flipped Class Manifest (Bennett, B.E., Bergmann, J.,Cockrum, T.,Fisch, K., Musallam, R.,Overmyer, J., Sams, A., & Spencer, D., 2012):

- Active and intentional transfer of some of the information delivery to outside of the classroom with the goal of freeing up time to make better use of the face-to-face interaction in school. This is often done with teacher created online videos (also referred to as screencasts or vodcasts).
- Teachers become guides to understanding rather than dispensers of facts and students become active learners rather than receptacles of information.

- Creating a permanent archived tutorial of class content. Advanced students may never need to watch the video again. All students can re-watch the video as needed. This frees more class time for data collection, collaboration, and application.
- Learners have immediate and easy access to any topic when they need it, leaving the teacher with more opportunities to expand on higher order thinking skills and enrichment.

The most common criticism of the flipped model is that it takes one ineffective method (in-class lecture) and simply uses technology to move the problem (online lectures). Proponents of the flipped model argue that it is how a teacher uses the newly freed class-time that is most important (Bergmann & Sams, 2012c). Offloading direct instruction to videos allows teachers to reconsider how to maximize individual face-to-face time with students. Time becomes available for students to collaborate with peers, engage more deeply with content, and receive immediate feedback from their instructor (Hamden, McKnight, McKnight, & Argstrom, 2013). The most important feature of the flipped class model is to increase teacher-to-student and student-to-student interaction during class time. Flipped teachers always say that the best benefit is that for the first time in their teaching careers, they have some one-on-one contact with every student during every class period (Moore, Gillett, & Steele, 2014). Ideally, the flipped model is a blending of direct instruction with inquiry-based learning. This allows more time for the development of 21st century skills, such critical thinking, collaboration, and self-direction (Framework for 21st Century Learning, 2010).

The Flipped Manifest (Bennett, et al., 2012) also states that:

Practitioners of the various flipped classroom models are constantly tweaking, changing, rejecting, adding to, and generally trying to improve the model through direct experience with how effective it is for kids. It's not "record your lecture once" and you're done; it's part of a comprehensive instructional model that includes direct instruction, inquiry, practice, formative and summative assessment and much more. It also allows teachers to

reflect on and develop quality and engaging learning opportunities and options for internalization, creation, and application of content rather than just fluff or time filling assignments. (p.1)

However, the flipped model still has many misconceptions. One is that the flipped model is about replacing teachers with videos (Nochese, 2011). There is a fear that the proliferation of online instructional videos will be used as leverage to diminish the roles of teachers. One example critics point to is the Khan Academy, which is a repository of over 4000 videos made by Salman Khan and whose videos have been viewed over 200 million times. Their goal is to change education for the better by providing a free world-class education to anyone anywhere (Khan, 2011). Critics have rightly then questioned the need for teachers. Salman Khan has endorsed the flipped model and has stated that his videos allow the teacher to focus on higher-level learning activities, such running simulations and labs with students, doing individual interventions, and facilitating peer-to-peer learning (Fink, 2011; Gojak, 2012). This emphasizes why the changes that occur in the classroom are the most important aspects of the flipped model.

The other misconception is that flipped learning is similar to an online course (Fink, 2011). Although online learning is-and will-continue to have a valuable place in the education spectrum, it must be noted that a flipped model does not change the amount of face-to-face time that a student spends in a classroom when compared to a traditional classroom.

Theoretical Framework for Mathematics and the Flipped Classroom

This research studies the effects of the flipped classroom model on mathematics and student achievement. Because the learning of mathematics is built upon a foundation of a student's prior knowledge, it is imperative that students understand the foundations before

progressing in the subject. In a hierarchically-organized subject, such as mathematics, failure to learn prerequisite skills is likely to interfere with students' learning of later skills. (Baxter Hastings et al., 2006; Brewer, 2009).

College Algebra

The national failure rate for college algebra is around 50% (Brewer, 2009), and much of this problem can be attributed to the case where students do not get adequate time or resources to understand a topic before moving on. The challenge of covering the entire mathematics syllabus while accommodating the needs of struggling students creates an almost impossible situation. Consequently, many students move through the college algebra curriculum with deficiencies (Gordon, 2005).

In college algebra, if a student does not understand the basic concepts, it is often very difficult for them to catch-up (Gordon, 2005). While there are many possible avenues to pursue while trying to improve these alarming statistics, practical realities often preclude drastic changes to programs and curriculum. Large-scale efforts to reform college algebra may not be possible in universities and colleges that base their programs on certain theoretical and practical considerations (Baxter Hastings, et al., 2006). Thus, efforts to solve the problem of helping students succeed should focus on interventions that can be implemented within the framework of existing programs. The traditional framework of most college algebra classes includes lectures provided by the instructor and homework completed by the student. If effective pedagogical changes can be made that fit within this traditional lecture-based framework, then it is more likely that these changes will be accepted and consistently used by the collegiate mathematics education community. (Brewer, 2009). Because the flipped model does not alter the student-

teacher interaction times and maintains an institutions course scheduling, a change to a flipped model is practical and reasonable. The flipped model and technological advances may allow instructors to discover new ways to learn about students, provide instant feedback, adapt instruction, and generally offer a high quality educational experience to all scholars (Manspeaker, 2011).

Technological Advancements

Students of the twenty-first century often know significantly more about computers than their teachers, and they prefer to access subject information digitally where it is more accessible (U.S Department of Education, 2010). With the advent of the Internet and streaming-video technologies, teachers are able to offer dynamic educational resources in multi-media, along with the capability to support alternate content delivery between instructors and learners. The tools of a flipped model are becoming more ubiquitous each year, both in and out of the classroom. Nearly all college students carry a smartphone, and many students prefer to receive information via smartphone or Internet (Dean, 2010). Schools and educators must be prepared for the blurring lines between technology, schools and learning. As Bonk (2009) stated recently in *The World Is Open: How Web Technology is Revolutionizing Education*:

> The Web 2.0 and its associated technology are among the latest fighting tools for change in education. Inevitably, there will be resistance to it. Many will argue that such hard to ignore. There are stockpiles of Internet technologies that are not simply fashionable but are part of the standard online learning lexicon, including asynchronous discussion forums, streaming video, and real-time chats. There really is no more debate here. Such technologies impact education in a major way today and will continue to do so

throughout this century; it is just a matter of figuring out exactly where, when, and how. (p. 44)

One complementary benefit of online learning and the use of the Internet in mathematics education is the ability for teachers to share resources. As Bonk (2009) remarked:

Educators have always wanted to share. Today they are sharing thousands of free educational items with unlimited access. And millions of people on planet Earth are browsing, using, and repurposing the content that they have shared. When thousands of course materials are accessed by millions of users, it is a sure sign of a learning revolution. (p. 68)

This sharing of educational resources has even warranted a new name: *E-Learning 2.0* (Downes, 2006). According to Downes, the Internet has been significantly transformed during the last decade. It has evolved from a highly popular medium for information transmission and consumption to a platform through which content is created, shared, remixed, repurposed, and passed along by its participants to potential users. Instead of being mere consumers of mathematical content, e-learning 2.0 allows inquiry-based learning to be much more feasible for mathematics students and allows for collaboration and constructivist activities. Bonk (2009) uses hyperbole to exclaim that e-learning 2.0 "harnesses the collective intelligence of individuals to situate us in a time of endless information abundance-the participatory learning age." (p. 88)

Educational Theory and the Flipped Model

Inquiry-based or constructivist learning is the philosophy that learning is the formation of abstract concepts in the mind to represent reality (Bruner, 1961; Piaget, 1968). Constructivism argues that the use of interactive activities in which learners play active roles can engage and

motivate learning more effectively than activities where learners are passive. The flipped model and online videos support the tenets of constructivism by freeing class time for inquiry-based learning (Brandt, 1997). The flipped model supported by the constructivist theory, should enable learners to engage in interactive, creative, and collaborative activities during knowledge construction (Kim & Bonk, 2006).

One critique of online video instruction in mathematics, is that concepts may be sacrificed for manipulative skill (Kennedy, 1990). However, the flipped model is a blending of direct instruction with constructivist learning, allowing students the complicated nomenclature of mathematics while freeing class time to teach students to *think* mathematically. Benjamin Bloom also emphasized the need to focus on higher level learning goals, not simply on basic skills. He noted:

> I find great emphasis on problem solving, applications of principles, analytical skills, and creativity. Such higher mental processes are emphasized because this type of learning enables the individual to relate his or her learning to the many problems he or she encounters in day-to-day living. These abilities are stressed because they are retained and utilized long after the individual has forgotten the detailed specifics of the subject matter taught in the schools. These abilities are regarded as one set of essential characteristics needed to continue learning and to cope with a rapidly changing world. (Bloom, 1978, p. 578)

Bloom's Taxonomy identifies different domains of learning, from the basic retention of facts to the application of knowledge which creates something new. Each domain has different levels; for example, below is the revised version of Bloom's taxonomy for cognitive learning (Anderson, 2000):

Bloom's Taxonomy

Creating

Evaluating

Analyzing

Applying

Understanding
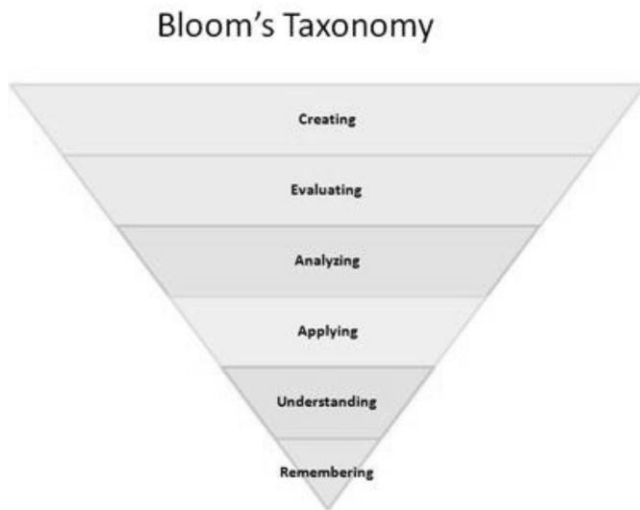
Remembering

Figure 1.1. A revised version of Bloom's Taxonomy for cognitive learning.

Applying Bloom's revised taxonomy to a flipped classroom, students are doing the lower

levels of cognitive work (remembering and understanding) outside of class, and focusing on the

higher forms of cognitive work (applying, analyzing, evaluating, and creating) in class, where

they have the support of their peers and instructor (Brame, 2013). The flipped classroom model

addresses this in The Flipped Manifest (Bennet, et al., 2011):

> Learners have immediate and easy access to any topic when they need it, leaving the
>
> teacher with more opportunities to expand on higher order thinking skills and enrichment.
>
> Offloading some information transfer allows a classroom to develop that understands the
>
> need for teacher accessibility to overlap with cognitive load. That is, when students are
>
> assimilating information, creating new ideas, etc. (upper end of Bloom's Taxonomy) the
>
> teacher is present to help scaffold them through that process. (p.1)

The flipped class model also meshes well with Vygotsky's theory of zone of proximal

development. Vygotsky believed that when a student is at the zone of proximal development for

a particular task, providing the appropriate assistance will give the student enough of a "boost" to achieve the task (Vygotsky, 1978). Once the student, with the benefit of scaffolding, masters the task, the scaffolding can then be removed and the student will then be able to complete the task again on his own. Vygotsky also views interaction with peers as an effective way of developing skills and strategies. He suggests that teachers use cooperative learning exercises where less competent children develop with help from more skillful peers within the zone of proximal development (McLeod, 2010). This matches well with the philosophy of the flipped classroom, where a teacher can utilize freed-up class time for collaborative work and individualized scaffolding of tasks.

Homework and the Flipped Classroom

Within mathematics education, it is assumed that understanding of a topic should occur when students complete their homework, receive feedback from their instructor on the correctness of their homework, and then reevaluate their approaches and learning (Zerr, 2007). However, this attempt-feedback-reattempt loop rarely achieves its theoretical potential in college algebra courses because students may not attempt their homework because it is not required or instructors may not be able to grade the homework because of time constraints (Jacobson, 2006).

One of the benefits of the flipped model is the ability of teachers to formatively access a student's homework deficiencies immediately in class. Likewise, corrective materials can be posted online available anytime and anywhere that an Internet connection is available. More advanced student's time is not wasted on remediation in class, and students needing remediation may review videos as needed.

Multiple Representations in Mathematics

In college algebra, multiple representations can refer to a graph, an equation, a table, and a verbal representation to represent a single mathematics problem (Kennedy, Ellis, Oien, & Benoit, 2007). When students learn how to use a variety of representations, they may be better equipped to solve a diverse array of problems. "The ways in which mathematical ideas are represented is fundamental to how people can understand and use those ideas" (National Council of Teachers of Mathematics, 2000, p. 67). Training in problem representation skills has been associated with success in solving algebra word problems (Schwarz and Hershkowitz, 1999). The understanding of multiple representations of a mathematics problem can be difficult for many students. A solution to this dilemma was proposed by Kaput (1989), who suggested the use of technology to dynamically link representations. For example, a table could be linked to a graph so that as values are entered into the table, they automatically appear on the corresponding graph. This would provide a connection from one representation to another to support learner understanding of the relationship between them. The support could be gradually lifted, allowing the technological representations to be used as a scaffolding mechanism.

Teacher created vodcasts used in a flipped classroom model can provide multiple representations through animations and interactive components which would be impossible with a traditional "chalk board" lecture. Because vodcasting allows for the video and audio capture of a teachers computer screen, it is easy to do demonstrations and lectures through interactive mathematical software, graphing calculators, and computer algebra systems. Because students can rewind and re-watch videos, students are given more opportunities to view the steps and link the multiple representations (Bowers & Zazkis, 2012).

Statement of the Research Problem

The mathematics achievement of America's college and university students is an issue of great concern to policy makers, as well as to educators. Many believe that mathematics achievement is a key predictor of a nation's long-term economic potential (Friedman, 2005). The pressure on educators to integrate computer aided instruction into their practice has grown substantially over the past decade. Educators and policy makers have incorporated technology recommendations into the *National Education Technology Standards for Students: The Next Generation* (2007). Each year, more than 1,000,000 students take college algebra (Lutzer, Maxwell, & Rodi, 2000). Moreover, failure rates in these courses are typically around 50%, and college algebra is often singled out as the one course that is most detrimental for a college students dropping out (Gordon, 2005; Brewer, 2009).

Online resources and technological tools are becoming more ubiquitous each year, both in and out of the classroom. Schools and educators need to be prepared for the blurred lines between technology, schools and learning. The popularity of the flipped classroom continues to expand, and there has been a continued call for quantitative research on the effects of the flipped model on student achievement (Berrett, 2012; Bishop & Verleger, 2013).

This research on the effects of a flipped classroom using teacher created online videos on student achievement in college algebra may provide valuable insight into more effective pedagogical practices in mathematics education.

Purpose and Significance of the Study

The purpose of this study was to investigate the mathematical achievement differences between students in traditional college algebra classrooms and college algebra classes taught

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using the flipped classroom method. The study was a quasi-experimental design, which is common to many studies involving human subjects, due to the difficulty of using randomized assignment of participants to groups. The dependent variable was mathematics achievement, and the independent variable was learning environment. In addition, it has been shown that there may be gender differences in learning and achievement of algebra (Hyde, Fenema, & Lamon, 1990; Tolar, 2007). Thus, gender was included in the analysis of the outcomes to see if gender moderated the effect of the flipped model and achievement. The study also investigated the interactions between learning environment and previous mathematics achievement.

This study may contribute to positive change in education, as it provides a researched-based foundation drawn from a mathematics setting that assesses the benefits of changing the paradigm for student achievement.

Research Questions

The study was designed to investigate the following research questions

1. Is there an overall difference in achievement between students in the traditional environment compared to students taught using the flipped classroom method?

2. Is there an interaction between gender and instructional method in regard to achievement?

3. Is there an interaction between prior achievement in mathematics and instructional method in regard to achievement?

Definition of Terms

Podcast – Any series of audio files that can be downloaded from the Internet, often released on some regular schedule. Podcasts are named after Apple Computer, Inc.'s iPod portable audio players, though most podcasts are in a format that can be played on virtually any computer or smart phone.

Vodcast – A vodcast is a podcast that also incorporates video in addition to audio. Vodcasting refers to teachers making and posting online videos.

Screencast – a synonym for a vodcast.

Smartphone – A cellular phone offering advanced capabilities, such as a PC-like operating system and Internet access.

Pre-Vodcasting –An instructional method in which the classroom teacher creates a vodcast of their classroom lecture on a topic or objective for viewing by students before attending class on that topic. The flipped classroom model was originally called the pre-vodcasting method.

Flipped Classroom – The flipped classroom is a model of teaching in which a student's homework is the traditional lecture viewed outside of class on a vodcast. Then class time is spent on inquiry-based learning which would include what would traditionally be viewed as a student's homework assignment.

Reverse Classroom – The reverse classroom is a synonym for the flipped classroom.

Digital Divide – refers to any inequalities between groups in terms of access to computer technologies including Internet access and communications.

Document Camera – Also referred to as a doc cam, is a desk mounted camera that projects and records a teacher's work. This can include projections of notes, textbook pages, worksheets, and calculators.

Camtasia – Camtasia is a software studio that provides screen video and audio capture. It is published by TechSmith. The user defines the area of the screen or the window that is to be captured. Camtasia also allows the user to record audio from an external or internal microphone. There is also an option to place a webcam's video footage in the corner of the screen.

Screencast.com –Screencast.com is a video storage repository similar to YouTube that is maintained by TechSmith and is linked with Camtasia. It differs from YouTube, in that the vodcasts are not public and commenting is disabled. The vodcasts are only available to students and teachers who have access to the direct link to the corresponding video.

Delimitations

For purposes of this study, the following potential delimitations are noted:

1. The data collected are from one medium sized state university and may not be completely applicable to similar interventions in different demographic environments.

2. The subjects were limited to college algebra students.

3. The study was limited to full-time and adjunct university instructors and graduate student instructors.

Assumptions and Limitations

For purposes of this study, the following potential limitations are noted:

1. The data collected represent performance from exams taken at the end of each semester, and may not reflect overall mathematics ability or retention.

2. The data collected are from college algebra and the intervention may not be applicable to similar interventions in different subjects or courses.

3. Data comparing student performance in traditional mathematics sections with data comparing student performance in the flipped courses may come from different teachers and thus may not be reliable comparison groups. That is, teacher variables outside the intervention may contribute to group differences.

This study used variables that relied on several assumptions related to mathematical understanding:

1. Mathematical understanding can be measured using end of semester exams.

2. Mathematical understanding can be improved through an instructor's delivery of content and students' mathematical practice.

It should be noted that with all research methodologies, the researchers need to be aware of the pitfalls inherent in any given methodology, in this case quantitative methods. Gall, Gall, and Borg (2003) stress that the researcher should carefully examine the reasoning and assumptions behind any elements included in a given study. This includes a careless discard of a null hypothesis (Type I Error) or the inclusion of one (Type II Error) that should be discarded, and warn that the researcher is accountable for power and significance of the results. Thus, attention was paid to the above accountabilities as the study moved forward included attention to assumptions about variables, attention to input of raw data patterns, avoidance of Type I and Type II errors, and care with statistical calculations and the interpretation of results.

CHAPTER 2

LITERATURE REVIEW

Introduction

In 2007, science teachers Jonathan Bergman and Aaron Sams were looking for a way to provide lectures to their students who missed class due to travel for athletics or activities. They created is a new movement in education called the flipped classroom method. Recently, articles on the flipped classroom have appeared in USA Today (Dell Cava, 2012), The New York Times (Rosenberg, 2013), The Economist (Flipping the Classroom, 2011), and the Washington Post (Strauss, 2012). Also, educators have appeared on 60 Minutes, the CBS Evening News, and CNN endorsing the flipped classroom concept. In early 2010, a professional learning network was created for educators interested in the flipped model. As of December, 2013, the network has over 16,000 members worldwide. This network provides both pedagogical and best-practice discussions as well as pragmatic support on technology and implementation (Overmyer, 2013).

The flipped model is most commonly being done using teacher created videos that students view outside of class time. It is called the flipped class model because the whole classroom/homework paradigm is "flipped". In simplest terms, what used to be classwork (the lecture) is done at home via teacher-created videos, and what used to be homework (assigned problems) is now done in class (Bergmann & Sams, 2012a). However, the flipped model is much more than the videos. The flipped classroom model encompasses any use of using Internet technology to leverage the learning in a classroom, allowing the teacher more time interacting with students instead of lecturing. Teachers feel that the human interactions that now occur in the classroom are the most significant aspects of the flipped model (Bergmann & Sams, 2012b).

With the proliferation of Internet technology, virtual communications, and learning management systems, many educators are interested in a flipped classroom (Berrett, 2012).

Mathematics education at the college level is facing many challenges. These challenges are occurring at a time when most experts believe that students are going to need stronger mathematical skills than ever before in order to compete in the workforce (National Council of Teachers of Mathematics, 2000). Many students are unprepared for collegiate-level mathematics, and efforts are being made to find better ways to help all students learn the mathematics they need to pursue their educational and occupational goals (Brewer, 2009).

Traditionally, collegiate mathematics education has been built around the lecture model. In this teacher-centered approach, the instructor spends most of the class time lecturing, answering homework questions, explaining mathematical rules, and working through numerous examples. This method has earned its current prominence because of the nature and amount of mathematics content covered in the classroom. However, other pedagogical methods are being explored, because of high failure rates of the traditional approach (Baxter Hastings et al., 2006). More student-centered approaches are being promoted, which encourage more student engagement (Huba & Freed, 2000).

One important study comparing face-to-face with online learning is a meta-analysis conducted by the U.S. Department of Education. In this oft cited meta-analysis, 45 studies were synthesized that compared face-to-face with online learning. The online learning could also include blended learning that incorporated both online and face-to-face instruction. Although online learning had a modestly higher effect than the traditional instruction, nine of the eleven individual studies with significant effects favoring the online condition used a blended learning approach (U.S Department of Education, 2010). Though the flipped classroom model was not a

term explicitly used in the study, the flipped model shares many of the characteristics of blended learning.

History of the Flipped Classroom

The concept of the flipped classroom and flipped learning is not new (Baker, 2000; Strayer, 2007). Before flipped classrooms, distance learning used instructional videos to deliver content. The idea that new technologies such as television and radio could be used to deliver education began to surface as long ago as the 1920s (Byrne, 1989). The Open University was the first, and most successful, full-scale effort to use video to deliver educational content. The Open University began in the 1960s in the United Kingdom to address the exclusion from higher education of people from lower income groups. Originally, the Open University was the "University of the Air", a daily distance education television program seen early mornings throughout the United Kingdom, Canada, and Australia (The Open University, 2013).

Over the years, the Open University has progressed along with technology to meet the needs of their students. In 2013, over 200,000 students were learning with the Open University, many of them accessing course materials on smartphones and tablets. Likewise, the Open University has a network of more than 5,000 tutors who provide support to students by email or computer conferencing (The Open University, 2013). Tutors also meet face-to-face with students to create active learning experiences beyond lecture (Tait, 2008).

While the Open University has been successfully using video instruction to deliver content, Baker had the idea to use electronic means to cover rote material outside of class (Baker, 2000). However, it was not until 1995, with the advent of an online content management system, that Baker was able to place lecture notes online, extend classroom discussions and use online quizzes (Strayer, 2007). Class time was then opened-up for students to work on applications of

the content and answer questions. Baker presented the concept to conferences between 1996 and 1998, and began to refer to the method as "The Classroom Flip" (Baker, 2011).

At about the same time, Lage, Platt, and Treglia designed and applied a similar procedure. They referred to the concept as "The Inverted Classroom" and similarly held the expectation that students would view lectures in advance of class, and then spend class time clarifying difficult concepts and working in small groups (Lage, Platt, & Treglia, 2000). They provided students with a variety of tools to gain first exposure to material outside of class, including textbook readings, lecture videos, and printable instructional slides (Johnson & Renner, 2012).

The modern use of online videos to supplement face-to-face instruction is often credited to Bergmann and Sams (Pink, 2010). In 2007, they were both science teachers at Woodland Park High School in Colorado. Because of the remote location of their school, they were finding that many students needed to leave early in the day to attend athletic events or other school related activities. Bergmann states that the early recordings were only for students who missed class (Bergmann & Sams, 2012a):

> Our absent students loved the recorded lectures. Students who missed class were able to learn what they missed. Some students who were in class and heard the live lecture began to re-watch the videos. Some would watch them when reviewing for exams. And we loved it because we didn't have to spend hours after school, at lunch, or during our planning time getting kids caught up. (p. 1)

Because their videos were posted publically online, they began receiving emails from students and teachers all over the world. Soon, they were travelling around Colorado doing professional development workshops on what they were calling the "pre-vodcasting" method.

Their workshops were meet enthusiastically because what they were doing was so simple, yet had the potential to reform education.

After scouring the Internet, they found that no one else was doing this method. The name was briefly changed to reverse instruction, but then, in 2010, Dan Pink wrote about the method and called it the flipped classroom and the term has stuck (Bergmann & Sams, 2012a). In March of 2011, Salman Khan used the term "flipping the classroom" in his TED talk (Khan, 2011). Since that point, interest in the flipped model has grown exponentially with new articles, press, and blogs on the flipped model appearing almost daily. News travels quickly, and soon, Bergmann and Sams were being asked to do their workshops all over the world.

Since 2009, Woodland Park High School has hosted a summer workshop for educators interested in the flipped learning model. Each year, attendance has risen sharply, and in June 2012, flipped educators provided a workshop for over 500 attendees (Overmyer, 2013).

The Flipped Learning Network

In 2010, the researcher created a social learning network website for teachers interested in the flipped model. This site was originally called the Pre-Vodcasting Network and was simply meant as a way for attendees of the various professional development workshops to keep the discussions going after the workshops. The site partnered with the official Flipped Learning Network, and it has evolved into a professional learning community with over 16,000 members (Overmyer, 2013).   It was in March of 2011 that Salman Khan of the Khan Academy mentioned "flipping the classroom" in his TED talk, and membership rapidly accelerated.

With over 16,000 members, the network has become a vibrant online community. These members come from over 45 different countries. This includes teachers from developed nations

such as the United States, Japan, Germany, and many from the United Kingdom, but also teachers from less expected countries such as Ghana, Luxembourg, and Bangladesh.

The network features over 50 groups. Many groups are subject specific, with the most popular ones being mathematics, chemistry, and foreign languages. These are used to discuss best-practices and pedagogy for those subjects. There also exist groups which are specific for help in implementing the flipped model such as "first time flippers", video creation software, and a group for using the Moodle learning management system (Overmyer, 2013). Likewise, there are several scores of discussion forums in the following categories:

- Learning Management Systems, Storing Videos and Online Assessment

- Making and Producing Vodcasts

- Resources and Links

- Articles, News, Results and Research

- Flipped Class Pedagogy and Classroom Management

- Conferences and Meetings

These forums run the gamut from in-depth discussions on implementing the flipped classroom, to dealing with parents and administrators and the day-to-day struggles of being a flipped classroom teacher. The forums are also used for questions on the technology used in the flipped classroom model. Techsmith, the maker of Camtasia screen-capture software, has technical support employees available to help network members.

In April, 2012 a survey was sent to members of the flipped class network (Kirch, 2012). Although less than 300 people responded to the survey, the following tables give a good indication of the flipped community subject demographics:

Table 2.1

Flipped Learning Network Survey Demographics

Subject Taught	N	Percentage
Mathematics	99	35%
Science	133	47%
Social Studies	25	9%
Literacy	17	6%
Foreign Language	14	5%
Other	22	8%

Criticisms and Misconceptions of the Flipped Classroom

One of the most common criticisms of the flipped model is that it is about replacing teachers with lecture videos (Nochese, 2011). There is a fear that the proliferation of online instructional videos will be used as leverage to diminish the roles of teachers and that videos are taking the poor pedagogy of lecture and simply putting it online (Waddell, 2012). One example critics point to is Khan Academy, which is a repository of over 4000 videos made by Salman Khan, and whose videos have been viewed over 200 million times (Khan, 2011). The videos were originally created for Khan's cousins to help him tutor them across the country. He started by posting 10 minute videos on YouTube. Eventually, these videos started to be viewed by the general public and were lauded for their clear explanations and easy conversational style of lecture. In 2010, the Bill and Melinda Gates foundation and Google became investors, and the Khan Academy has grown ever since (Dell Kava, 2012). Their goal is to change education for the better by providing a free world-class education to anyone anywhere (Khan, 2011).

Critics have rightly questioned the need for teachers. Salman Khan has endorsed the flipped model and has stated that his videos allow the teacher to focus on higher-level learning activities, such running simulations and labs with students, doing individual interventions, and facilitating peer-to-peer learning (Fink, 2011; Gojak, 2012). This emphasizes why the changes that occur in the classroom are the most important aspects of the flipped model.

The Khan Academy is receiving its share of criticism, mostly from people who claim that a classroom-based teacher's importance is diminished by this technology. "If a teacher is just lecturing like a computer might, maybe that teacher should be replaced. But the truth is, most teachers don't just drone on, they educate (Della Cava, 2012, p. 2)," says Noschese, a physics teacher at John Jay High in Cross River, N.Y., whose personal website dedicates a tab to Khan Academy criticism (Noschese, 2011). Educators are also quoted as saying the Khan Academy is "one of the most dangerous phenomena in education today." That quote is not directed at the site itself, but revolves around the negative impact Khan may have on actual teaching and learning. The Khan style of teaching is the same step-by-step process that students have seen for generations. "Khan Academy is great for what it is a supplemental resource; homework help, but we've turned it into something it's not. Indeed, something it was never intended to be (Makice, 2012, p. 2)."

Bergmann and Sams argue that in a flipped learning environment, the role of teacher is amplified, in that all teachers now must know the individual learning needs of each student as their daily interactions increase. This actually increases the need for qualified, professional and caring educators. "Although video can be leveraged to deliver direct instruction, it does not, and cannot, replace the teacher as the facilitator of learning. (Bergman & Sams, 2012, p. 3)"

Another misconception is that flipped learning is similar to an online course (Fink, 2011). Although online learning is-and will-continue to have a valuable place in the education spectrum, it must be noted that a flipped model does not change the amount of face-to-face time that a student spends in a classroom compared to a traditional classroom. However, the original definition of the flipped classroom, "what used to be classwork (the lecture) is done at home via teacher-created videos, and what used to be homework (assigned problems) is now done in class (Bergmann & Sams, 2012b)", can imply that the flipped model can simply be online video lectures at home and a static use of class time for students to passively work on homework problems. This has led The Flipped Learning Network (2014) to release an updated and revised formal definition of flipped learning:

> Flipped Learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space in transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter. (p.1)

This new definition emphasizes that in flipped learning, the way face-to-face time is spent is most important.

Waddell (2012) argued that the videos are just taking a bad pedagogy (the in-class lecture) and putting it online. In fact, he argues that this is even worse as there is no chance during the videos for inquiry or collaboration. Yet he does concede that there would be greater classroom time for these activities. Critics also claim that it just reinforces the "sit-and-get" aspect of education without deeply engaging students (The Economist, 2011). Aaron Sams concurs: "Anyone who blindly adopts 'The Flipped Classroom' (or inquiry, or lecturing, or

unschooling, or whatever) model and never modifies it to meet the needs of his or her students will blindly lead his or her students into educational ruin." (p. 39)

Additionally, there are pitfalls that educators must be aware of when attempting to implement the flipped classroom model. First, students new to the method may be initially resistant because this new type of schooling requires them to do work at home rather than first be exposed to content and subject matter in school (Freeman Herreid & Schiller, 2013). Likewise, video quality is important. Teachers need to either carefully curate the videos from pre-made video sites or make their own videos (Flipped Learning Network, 2014). Both of these methods require an ample commitment of time from educators, and teachers must be prepared for the increased workload (Freeman Herreid & Schiller, 2013).

Ineffectiveness of Lecture

A recent meta-analysis was conducted to test the effectiveness of constructivist versus lecture-centered in undergraduate science, technology, engineering, and mathematics (STEM) courses (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt, & Wenderoth, 2014). To be included in the meta-analysis, the courses had to contain at least some aspect of active learning and included approaches such as group problem-solving, worksheets or tutorials completed during class, peer instruction, and use of personal response systems. The analysis looked at 225 studies and found overall mean effect size for performance on identical or equivalent examinations, concept inventories, and other assessments was a weighted standardized mean difference of 0.47. This shows that, on average, student performance increased by just under half a standard deviation with active learning compared with lecturing (Freeman, et al., 2014). Likewise, student achievement was higher with active learning compared to lecture learning

when the measure of achievement was a concept inventory, as opposed to instructor-written course examinations. Freeman, et al. (2014) argue that the higher gains concept inventories may be due to concept inventories measuring higher level cognitive skills and that active learning has a greater impact on student mastery of higher level learning.

Eric Mazur, a peer-instruction advocate and professor who has long campaigned against the lecture model (Mazur, 1997), commented on the Freeman, et al. (2014) meta-analysis, "It's good to see such a cohesive picture emerge from their meta-analysis. An abundance of proof that lecturing is outmoded, outdated, and inefficient (Bajak, 2014, p. 2)." Likewise, Freeman stated that under active learning

> Students learn more, which means we're doing our job better. They get higher grades and fail less, meaning that they are more likely to stay in STEM majors, which should help solve a major national problem. Finally, there is a strong ethical component. There is a growing body of evidence showing that active learning differentially benefits students of color and/or students from disadvantaged backgrounds and/or women in male-dominated fields. It's not a stretch to claim that lecturing actively discriminates against underrepresented students. (Bhatia, 2014, p. 4)

The results of the study are similar to a meta-analysis by Springer, Stanne, and Donovan (1999), which showed the effects on student achievement of cooperative learning in undergraduate STEM courses. In this study the mean difference effect size was found to be Cohen's $d=0.51$ for students exposed to small groups compared with students without cooperative instruction for achievement. Furthermore, the positive effects on achievement of African American and Latino students had an effect size of Cohen's $d=0.76$ (Springer, Stanne, & Donovan, 1999).

The Role of the Instructor

One of the important factors in the flipped classroom model is the role of the instructor. The flipped classroom requires that the instructor create an inquiry-based teaching environment, where the face-to-face class time shifts from a teacher-centered space, to a student-centered space (Bergmann & Sams, 2012a). The traditional educational system was created using the factory model of management with the idea of top-down instruction, and "sage on the stage" teachers who produce outputs, or students who pass standardized tests (Howell, 2013). However, a paradigm shift is occurring where learning began to be about students and their needs. "Since the turn of the century, the challenges of globalization, information technology, international competition, and strong local developments have stimulated a new wave of educational reforms" (Cheng & Mok, 2008, p. 374). The new wave has shifted from a teacher-centered paradigm to a student-centered one. Cheng and Mok (2008) described this new paradigm as one where learning should be tailored to meet the needs of the individual student. It is one where the focus of learning shifts to how to learn, create, think, and develop with the ultimate goal being lifelong learning.

In a student centered classroom, teachers act in an interactive manner, mediating the environment for students as opposed to behaving in an instructive manner, disseminating information to students. In addition, teachers in student-centered classrooms seek the students' points of view and correct misconceptions, as opposed to seeking the correct answer to validate student learning (Johnson & Renner, 2012).

Flipped educators have endorsed the switch from a teacher-centered classroom to a student-centered classroom, and emphasize that switching from "sage on the stage" to "guide on the side" is an essential element of flipped learning (Baker, 2000; Bergmann & Sams, 2012a;

Musallam, 2011). Kirch, a high school mathematics teacher who has embraced the student-centered classroom, understands that the flipped model is about much more than the videos. She reports that the flipped classroom ideology has allowed her to, "interact with every student (all of them) on a daily basis in at least a short math-related conversation" and "be able to more easily and readily assess student mastery of the content on a daily basis and provide the immediate support they need to succeed (Kirch, 2012, p. 4)." Musallam (2011) suggests that teachers preparing for the flipped classroom should take the teacher-centered aspects of their instruction and choose this to be the content of the instructional videos.

However, even though many teachers may have intentions of creating a student-centered classroom, many do not have the training or experience to implement this in the classroom. Likewise, a lack of content knowledge often leads to a teacher-centered classroom (Johnson & Renner, 2012), regardless of the teacher's intentions.

Possible Benefits of the Flipped Classroom

The flipped classroom model may provide many benefits for instruction that are not possible with traditional instruction. Supporters argue that the videos maximize class time to promote the exact deeper, inquiry-based learning that the critics bemoan (The Economist, 2011). Proponents of the flipped model argue that it is how a teacher uses the newly freed class-time that is most important (Bergmann & Sams, 2012a). Offloading direct instruction to videos allows teachers to reconsider how to maximize individual face-to-face time with students. Time becomes available for students to collaborate with peers, engage more deeply with content, and receive immediate feedback from their instructor (Hamden, McKnight, McKnight, & Argstrom, 2013). The most important feature of the flipped class model is to increase teacher-to-student and

student-to-student interaction during class time. Teachers using the flipped method say that the best benefit is that for the first time in their teaching careers, they have some one-on-one contact with every student during every class period (Moore, Gillett, & Steele, 2014). Ideally, the flipped model is a blending of direct instruction with inquiry-based learning. This allows more time for the development of 21st century skills such critical thinking, collaboration and self-direction (Framework for 21st Century Learning, 2010).

The Flipped Manifest (Bennet, et al., 2011) states that:

> Practitioners of the various flipped classroom models are constantly tweaking, changing, rejecting, adding to, and generally trying to improve the model through direct experience with how effective it is for kids. It's not "record your lecture once" and you're done; it's part of a comprehensive instructional model that includes direct instruction, inquiry, practice, formative and summative assessment and much more. It also allows teachers to reflect on and develop quality and engaging learning opportunities and options for internalization, creation, and application of content rather than just fluff or time filling assignments. (p.1)

Salman Khan has endorsed the flipped model and has stated that his videos allow the teacher to focus on higher-level learning activities, such running simulations and labs with students, doing individual interventions, and facilitating peer-to-peer learning (Fink, 2011; Gojak, 2012). This emphasizes why the changes that occur in the classroom are the most important aspects of the flipped model.

The flipped classroom model may also have benefits in reducing anxiety in difficult, content heavy courses. The Washington Post (Strauss, 2013) article details Stacy Roshan who teaches AP Calculus using the flipped classroom model at a private school in Potomac,

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Maryland. "My AP Calc class was a really anxious environment," said Roshan. "It was weird trying to get through way too much material with not enough time. It was exactly the opposite of what I was looking for when I got into teaching (Strauss, 2013, p. 1)." She learned about the flipped classroom at a technology conference and realized that it would allow her to get the lecture out of the classroom and provide one-on-one time with students. Because it is an intensive AP course, Roshan creates about 4 videos per week with a length of 20 to 30 minutes each. Students say they often spend much more time than this viewing, as they rewind to parts they didn't understand the first time through. In class, student work with Roshan and other students on problems. Students like the method because they no longer have to sit at home and struggle with confusing homework. Students also feel that it is much easier to learn calculus, and that the method has reduced math anxiety (Strauss, 2013).

The flipped method may also have benefits with at-risk students. One example is an economically challenged school next to Detroit with 75% of students receiving free or reduced-price lunch, with many students commuting from Detroit. The main issued facing the school was failure and drop-out rates (Pearson Case Study, 2013). The school's principal reversed the instructional procedures so that students did homework at school. Video lessons were created by teachers for students to view on-demand. Unlike many flipped models where students were expected to view videos outside of class time, students in this school could view the videos with headphones during class as needed. Green (2012) states:

> By reversing our instructional procedures so that students do their homework at school, we can appropriately align our learning support and resources for all of our students, and eliminate the inequality that currently plagues our schools. When students do homework at school, they can receive a meal and access to technology (during a

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declining economy), and an overwhelming amount of support and expertise. When students do their homework at school, we can ensure that they will be able to learn in a supportive environment that's conducive to their education and well-being. For the first time in history, we can provide a level playing field for students in all neighborhoods, no matter what their financial situation is. (p. 10).

It should be reiterated that a flipped model does not change the amount of face-to-face time that a student spends in a classroom when compared to a traditional classroom. For the flipped classroom to have possible benefits, the goal of online videos is not to replace in-class learning, but to instead supplement and enhance the learning and, face-to-face time should promote deeper, inquiry-based learning.

Key Research on the Flipped Classroom Model

This literature review will summarize and discuss some of the key findings in the research on flipped learning in undergraduate STEM education. In addition, three studies from upper level high school mathematics are included because these course are similar to college algebra.

Research on Flipped STEM Education

All of the studies found on the flipped classroom model in undergraduate education were in the STEM fields. This is not surprising since these are the subjects which are most commonly flipped (Overmyer, 2013). This section reviews the studies that were not mathematics, and include such topics as introductory biology, pharmacy therapeutics, and computer literacy. Research on flipped mathematics course will be included in the subsequent section.

Students in introductory biology taught at the University of California, Irvine were taught using "learn before lecture" techniques between 2007 and 2009 (Moravec, Williams, Aguilar-Roca, O'Dowd, 2010). The researchers did not use the term "flipped" or "inverted", but the methods had similarities. Their method was quite basic, and simply involved removing 4 or 5 lecture slides from the previous year's lectures and creating narrated PowerPoint videos. One of their concerns was that teachers of large introductory classes at research universities have little interest in making major revisions to their courses.

Instead of a complete overhaul of the course, they created pre-class assignments that combined narrated video with note taking sheet. The school was interested in implementing higher-level concepts during engagement exercises already scheduled into the class, but did not want to have to create additional lab sections. The course designers stated:

> Theoretically, this could be accomplished by students completing assigned readings before class but in our experience this rarely occurs, even when coupled with pre-class quizzes worth a small number of points. We therefore created pre-class assignments designed to help students learn knowledge-level material in preparation for lecture. (Moravec, et al., 2010, p. 3)

The intervention group consisted of students who received the pre-class video assignments in 2009 and the control group was classes from 2007 and 2008, before the pre-class video assignments. The measure of learning was related question pairs, matched by level and format. The mean increase in performance was 21%, and the percentage of students who correctly answered five of six exam questions was significantly higher ($p<.001$) in 2009 versus the previous years.

Another study compared students' course achievement in computer literacy at Uludag University in Turkey. The research used two instructional methods. The first method was a traditional face-to-face lecture and the second method was a blended model that had some similarities to a flipped learning format. The research used a pretest-posttest model with a control group/intervention group design. The participants were assigned to groups purposefully to achieve group equivalency, based on test scores examining prior knowledge about computers.

The face-to-face group had two hours of traditional classroom time and two hours of applied laboratory material per week. The traditional class time was not just lecture, but included classroom discussions, projects and collaborative learning. The blended classes only meet face-to-face for two hours per week. This differs from a flipped classroom model, where face-to-face time is not changed from the traditional model. However, similar to a flipped model, the blended classes had a website that provided multimedia components, such as screencasts, assessment simulations, and online tutorials.

The achievement test consisted of questions from the courses final exam and was also used to test students' prior knowledge as the pretest. The same exam was given as the pretest and the posttest. The test was prepared by four instructors of the course. The course ran for fourteen weeks with 86 students finishing the blended model and 93 students taught in the traditional model. An independent samples t-test was applied to the mean posttest scores to examine the differences in course achievement. There was a statistically significant difference, $t(177)=6.913$, p<.001, with the blended group outperforming the strictly face-to-face group.

Table 2.2

Comparison of Blended and Face-to-Face Posttest Scores

Group	N	Mean	SD	df	t	p
FTF	93	51.16	9.97	177	6.913	0.000
Blended	86	61.49	10.003			

This results in a Cohen's *d*=1.04. This indicated that treatment had a "large" effect using Cohen's terminology (Cohen, 1998). The results indicate that the combination of online and face-to-face instruction had a positive influence on student achievement. The report claims that the "benefits of blended learning environment with interactive materials including instructional videos, screen captures, and assessment simulations are the most effective factors for success (Uzun & Senturk, 2010)." They also claim that students are much better equipped to learn procedural skills with video, as they are able to pause and rewind, which is not possible in a traditional teaching environment. All of these aspects of the blended model are also characteristics of the flipped learning model.

A project from 2012 assessed the impact of the flipped classroom model on student performance and perceptions in an 8 week pharmacy integrated therapeutics course (Pierce & Fox, 2012). The course used process-oriented guided inquiry learning (POGIL) which actively engages students to develop critical thinking and problem solving. Originally designed for college chemistry, POGIL has been expanded to many disciplines and has been endorsed by the National Science Foundation for showing positive results in undergraduate science courses (Lewis & Lewis, 2005).

The research compares students' achievement between a traditional pharmacy course from 2011 and a flipped classroom/POGIL based course in 2012. For the 2012 course, students

viewed vodcasts of lectures prior to the scheduled class and then discussed interactive cases of patients in class. For each class, a POGIL activity was developed and implemented that supported and provided application of the material contained in the previously viewed vodcast lectures.

The same instructor taught the courses in 2011 and 2012 and covered identical material and gave identical final exams. The final exam consisted of 16 multiple choice questions. A t-test was performed to analyze differences. It was found that the flipped class in 2012 performed statically significantly better than the traditional 2011 class with $p = 0.024$ (Pierce & Fox, 2012). Student's perceptions of the flipped classroom were also explored. A ten question Likert scale survey instrument was administered. Results showed that 90% percent of the students agreed that the instructor made meaningful connections between the topics in the vodcasts and the class activities. Likewise, eighty percent agreed that the flipped model improved their self-efficacy and improved their confidence on the final exam. Nearly two-thirds expressed a desire for more instructors to use the flipped classroom model.

The study concluded that the flipped model improved student performance and perceptions and felt that the contributing factors included student contact with the material prior to class (the vodcasts), frequent and formative assessments prior to the final exam, and interactive and group-based class activities (Pierce & Fox, 2012).

A similar study reported on an implementation of the flipped classroom of three sections in an IT 101 (Introduction to Information Technology and Computing Concepts), an introductory IT course required by all first year students at a small business university (Frydenburg, 2012). The course covers digital literacy topics, basic web development, maintaining laptops, wireless

networking, and current web trends. Approximately 40% of the course covers topics in Excel spreadsheet software, and this was the only part of the course flipped.

Before implementing the flipped model, the instructor would explain Excel concepts in class, or demonstrate a tutorial from the textbook during class, as students tried to follow along on their laptops. They would then go home to complete the mastery exercises. In implementing the flipped classroom, the students watched the instructional videos before class, and there were no in-class demonstrations or lectures. Students would work on completing an in-class group activity with the instructor readily available to complete the exercises. Classes met in 75-minute blocks with five minutes for announcements, five minutes for a quiz based on the videos, five minutes to explain the in-class activity, 45 minutes to complete the activity, and 15 minutes to debrief and have groups share their solutions. The researcher asserts that this created an active learning experience where students engaged in open-ended and learner-centered activities, collaborative problem solving and required public articulation of the concepts with the group sharing.

To confirm and access if students watched and retained the content of the videos, a five-minute, five-question multiple choice quiz was delivered in class. Students completed the quiz by logging onto the Blackboard learning management system online. The study did not state if the students were required to bring an Internet accessible device to class, or if the classroom had a one-to-one computers. The researcher states that the quizzes motivated students to watch the videos, as each quiz counted toward the course grade.

To determine the impact of flipping the course, the author administered a voluntary online survey to all 66 students. There was no control group, and the research does not measure student achievement. All three sections were taught by the same instructor. Since there was no

experimental design, all of the outcomes were descriptive. Over 90% of the students felt that the flipped classroom helped them learn the material better than a traditional classroom. Likewise, over 90% of the students agreed that the structure of the course made the class more personal and helped them connect with other students. The videos made by the student tutors were well received by the class with a strong majority responding that the videos were clear and short enough to convey the concepts. The only negative reported in the surveys was in the large lecture section. Students responded that the class was too big for one instructor to facilitate and groups had to wait too long for assistance. The article states that smaller class size and a classroom with tables rather than rows of fixed seating is more conducive for implementing a flipped classroom and the ability for the instructor to circulate among the students is crucial.

Research on Flipped Mathematics Education

The research on flipped undergraduate mathematics is meager; therefore, the following summaries include three upper level high school mathematics courses. This is followed by a summary on undergraduate linear algebra. In all cases, the courses used videos to be viewed outside of class time, and face-to-face time was spent on homework or inquiry-based learning assignments.

One study looks at a flipped model in AP Calculus (Strauss, 2012). The instructor created about four videos per week with a length of 20 to 30 minutes each. This method is unique, in that the videos were not all created in advance, but were often created only a few days in advance. This allowed the instructor to customize the videos based on the progress of the course (Roshan, 2011). The following shows the AP Calculus exam results (Roshan, 2011):

Table 2.3

AP Calculus Exam Results

		AP Score					
Year	n	5	4	3	2	1	Average Score
2009-10 (Traditional)	10	23.53%	35.29%	23.53%	11.76%	5.88%	3.59
2010-11 (Flipped)	17	33.33%	44.44%	22.22%	0%	0%	4.11

The AP Calculus exam is scored on a scale of 1 to 5. A score of 3 is sometimes good for college credit (Grove, 2011). It should be noted that the sample size here is small and that the instructor had an extra year of overall teaching experience during the flipped year. However, the fact that all students scored at least a 3 on the exam with the flipped method is encouraging.

Another study of higher level high school mathematics was research with Faulkner, math teacher at Byron High School in Byron, Minnesota (Pearson Case Study, 2013). Faulkner began the flipped model in mathematics in the fall of 2010. In addition to spending class time on individual and group assignments, Byron High School uses peer instruction where students answer questions individually and then work in groups to convince their peers that their answers are correct (Mazur, 1997).

In surveys administered by Byron High School mathematics teachers, 87 percent of parents and 95 percent of students said that they preferred flipped learning to the traditional lecture format for mathematics. Many students commented that they prefer interacting with others during class time, having help available in-class, and having the ability to re-watch the lectures if needed. Faulkner also stated that because of the increased one-on-one time with students in class, teachers and students are building better relationships.

Faulkner compared the achievement of the students, comparing the pre-flipped years of 2007-2010 with the fully flipped years of 2011-2013. Results show the number of student scoring proficient or above in Algebra 2 increased by 12 percentage points, in pre-calculus by 11 percentage points, and in Calculus I by 9 percentage points. The study did not report which assessment was used for these results and other variable could have influenced these results. However, overall, they show that the flipped learning model is showing signs of success in these mathematics courses.

A similar study was conducted on an honors analysis/pre-calculus classes for high school juniors and seniors (Kirch, 2012). During the 2010/11 school year the classes were not flipped and all lessons were taught in class, and all practice was done at home by students.

During the 2011/12 school year, the teacher began a trial of the flipped classroom during the fall semester and transitioned to a fully flipped class during the spring semester. This flipped classroom included all lesson instruction being done via video and most practice done in class. The instructor produced all of the videos. Students were required to watch the lesson, write a summary, and ask a higher-order thinking question at home. In class, students reviewed the lesson, answered their questions, and worked on practice. Activities and methods were structured, but "varied based on content and throughout the week to mix things up." (Kirch, 2012, p. 4)

The teacher kept all instruction, supplementary materials, quizzes, tests, practice assignments, and online resources identical during the pre-flip year and in the flipped classroom. The study also stated that student demographics from both years were similar in terms of number of students, grade levels of students, and general class environment. Results showed a 5% increase in class averages from the pre-flip year to the flipped class using identical measures.

Likewise, results showed in 12% increase in students receiving final grades of A or B, with a nearly 10% decrease in students failing the course. There were no reported means, sample sizes, or standard deviations, so statistical significance and effect sizes could not be determined.

One study provided quantitative experimental research on the effects of flipped learning on students' achievement. The study compared a section of linear algebra taught in the traditional lecture style, with a section of linear algebra taught in a flipped model (Love, Hodge, Grandgenett, & Swift, 2013). The same instructor taught both sections, and the course was mostly undergraduate sophomores in applied linear algebra. Of the 55 students who agreed to participate in the study, 27 were in the flipped section and 28 were in the traditional section. Students were not given a choice regarding the method of instruction. The instructor was teaching two sections of the course and arbitrarily chose one to be flipped and the other to be traditional. The students selected the time slot that fit into their schedules and were unaware of the method of instruction until the first day of class. Students in both sections completed the same work.

The screencasts were developed specifically for this course by the instructor. The screencasts were recorded on the instructor's computer and consisted mostly of the instructor narrating the presentation slides. Occasionally, the instructor would switch to a Maple (mathematics and engineering software) session to illustrate concepts graphically. In the flipped section, class time was reserved for engaging students in organized, interactive, hands-on activities. Specifically, students in the flipped classroom section spent most of their class time working problems on the board in pairs.

Students in the flipped section were also required to complete pre-class daily readiness assessments via the course learning management system, which were designed to assess learning

and to provide students an opportunity to ask for more explanation about certain topics in class. Each readiness assessment consisted of three questions. The first two questions related directly to the content, but were designed to promote mathematical thinking and were not simply a repetition of definitions. The third question was open ended and asked what the student found difficult, confusing or interesting in the video lesson. The answers on the third question were used to guide the instructor in what to discuss and cover in upcoming classes.

The traditional section was the control group, and the flipped section was the experimental group. The dependent variables were student scores on three common midterm exams and a comprehensive final exam. Each of the two sections met for two 75-minute classes each week. The traditional section was taught with roughly the first half of the each class period used for questions and the instructor working some of the homework problems on the board. In the second half of the class, the instructor lectured on new material and worked through some example problems. In the flipped section, the first 15 minutes or so of each flipped class were spent in instructor-led discussion with students. The instructor discussed the daily readiness test questions and addressed student questions including both those posed before class and during class. For the remainder of the class, students typically worked on some even-numbered problems from the textbook.

Though students were accessed on three common midterms and a common final exam, data was not given for the midterms. The only analysis was that the performance on the second exam relative to the first exam, the average change in score for the students in the flipped section was significantly greater than for those in the traditional section ($p < 0.034$). When comparing the third exam to the first exam, the average change in score for those in the flipped classroom section was again significantly greater than for those in the traditional section ($p < 0.012$). The

analysis was done using the non-parametric Mann-Whitney U test, because the data was not normally distributed, precluding the use of a traditional two-sample t-test. A simple descriptive comparison showed that average raw score in the flipped section was 89.5 compared to 87.4 in the traditional lecture section (Love, Hodge, Grandgenett, & Swift, 2013). The article did not state a standard deviation so an effect size was unobtainable from the given data.

A survey was given at the end of the semester. Results showed that 74% of students in the flipped section had a positive attitude about the flipped classroom approach. The survey showed that 78% agreed that the group work helped them to become socially more comfortable with their classmates, and over 70% agreed that explaining a problem or idea to their partner helped them to develop a deeper understanding of the material.

One important result was that students in both sections were asked if they were more comfortable talking with classmates in this class than other mathematics courses they had taken. Almost 56% of students in the flipped classroom section agreed with this statement. While this may not seem like a large value, only 21% of students in the lecture agreed with the statement. The summary stated that even though the results on the common final exam were similar, the surveys showed that the students in the flipped section enjoyed the class more and that retaining interest is an important facet for STEM majors (Love, Hodge, Grandgenett, & Swift, 2013).

Summary

The flipped classroom model came about from a confluence of video lecture first seen in distance education, inquiry-based learning principles, learning management systems, and learning technologies that enabled teachers to create their own online videos.

Most of the literature suggests that the flipped learning model is showing success, including success in college-level student achievement and mathematics. One common theme is that one of the most important aspects of the flipped model is not the videos, but the changed use of the face-to-face class time. However, this has not prevented some dissonance in the education community, as some critics may see the flipped model as a way to simply deliver content online to diminish the role of the classroom teacher (Fink, 2011; Nochese, 2011). It should be reiterated that a flipped model does not change the amount of face-to-face time that a student spends in a classroom when compared to a traditional classroom.

Flipped educators caution against blindly adopting the flipped classroom model without prudently considering the needs of their students (Bergmann & Sams, 2012c; Hamden, et al., 2013; Bennett, et al., 2012). The flipped classroom represents a unique combination of active, face-to-face, inquiry based learning combined with direct instruction delivered asynchromusly through online video (Bishop & Verleger, 2013). The rise in popularity and press on flipped learning has caused a synergistic rise in the publicity and implementation of the flipped classroom model. Likewise, it is the convergence of technologies which has taken place in past couple of years that has allowed for this innovation in education.

CHAPTER 3

METHODOLOGY

This research studies use of the flipped classroom in college algebra and its effect on

student achievement. The flipped classroom model encompasses any use of using Internet

technology to leverage the learning in a classroom, so that a teacher can spend more time

interacting with students instead of lecturing. This is most commonly being done using teacher

created videos that students view outside of class time. It is called the flipped class model

because the whole classroom/homework paradigm is "flipped". In its simplest terms, what used

to be classwork (the lecture) is done at home via teacher-created videos, and what used to be

homework (assigned problems) is now done in class (Bergmann & Sams, 2012a).

This research compares the flipped classroom model with traditional lecture courses in

college algebra. In the flipped class sections, teachers created online videos of their lectures with

students viewing them and taking notes before attending class. Students then work in class on

inquiry-based assignments, including what is traditionally thought of as homework. This

completely changes the paradigm of teaching, thus creating the flipped classroom.

The popularity of the flipped classroom continues to expand, and there has been a

continued call for quantitative research on the effects of the flipped model on student

achievement. The purpose of this study is to investigate the mathematical achievement

differences between students in college algebra classrooms taught by instructors using the

flipped classroom method with instructors using the traditional lecture method. In addition, it has

been shown that there may be gender differences in learning and achievement of algebra (Hyde,

Fenema, & Lamon, 1990; Tolar, 2007). Thus, gender was included in the analysis of the outcomes to see if gender moderated the effect of the flipped model and achievement.

The study is a quasi-experimental design, which is common to many studies involving human subjects (due to the difficulty of using randomized assignment of participants to groups). The primary dependent variable is mathematics achievement, and the primary independent variable is learning environment.

Research Questions

The study was designed to investigate the following research questions

1. Is there a difference in achievement between students in the traditional environment compared to students taught using the flipped classroom method?

2. Is there an interaction between gender and instructional method in regard to achievement?

3. Is there an interaction between prior achievement in mathematics and instructional method in regard to achievement?

Research Design

This study uses a quantitative quasi-experimental design to compare college algebra achievement among the following groups:

1. Control group: Students taught the college algebra using the university's traditional method of in-class lecture with assigned homework. (N=166)

2. Intervention group: Students taught college algebra by instructors using the flipped classroom method. (N=135)

The dependent variables are students' mathematics achievement on a common final exam and scores on a pre/post algebra readiness exam. The independent variables are learning environment based on the groups, with additional independent variables of gender and ACT mathematics scores.

The first analysis was with the dependent variable of achievement on a common final exam.

E: X_1 O_{Final}

C: X_2 O_{Final}

The design was a t-test to compare common final exam scores. Multiple regression was used to investigate interactions. Multiple regression modeling is used to analyze situations in which there are several independent variables. In this case, the independent variables are treatment group, ACT mathematics score, and gender. The ACT mathematics scores were centered by subtracting the group mean from each value. Multiple regression modeling tells how these independent variables interact with each other and what effects these interactions have on the dependent variable. It allows us to predict final exam scores after accounting for gender and ACT scores.

The second analysis was with the independent variable of pretest and posttest scores on the algebra readiness exam.

E: O_1 X_1 O_2

C: O_1 X_2 O_2

The design was an ANCOVA with two between groups independent variables (instructional method and gender), one independent variable of the algebra readiness exam posttest and the algebra readiness exam pretest as a covariate.

Rationale for the Research Design

To answer the research questions, the literature suggests the use of multiple regression, and ANCOVA (Field, 2005; Gliner & Morgan, 2000; Leech, Barrett, & Morgan, 2004). The multiple regression model is applicable in determining main effects between instructional method and mathematical achievement on the final exam, as well as effects or interactions among gender, ACT scores, instructional method, and final exam scores. The ANCOVA is appropriate for the algebra readiness exam because there are two between-groups independent variables (instructional method and gender), one independent variable of the algebra readiness exam posttest, and the algebra readiness exam pretest as a covariate. (Gliner & Morgan, 2000).

 Setting

The setting to examine differences in mathematics achievement between the experimental groups and the control group classrooms will take place in a medium-sized university with a student population of approximately 12,000. Approximately 69% of all undergraduate students are 24 years old or younger. One-third is first-generation college students, and roughly one-third is low-income (Pell grant eligible). This school was chosen for the study out of convenience. The mathematics department allowed certain sections to be taught with the experimental flipped classroom method and other sections to be taught with the control group traditional method.

College Algebra was specifically chosen because:

- There are a large number of sections and students.

- The course has a traditionally high failure rate.

- The content of college algebra at this university is similar to college algebra
  courses nationwide and is representative of a robust, challenging course with
  broad content and deep understanding required.

Participants

The accessible population in this study is all students at the university taking College Algebra during the fall 2012 semester. Participants in the intervention group were five sections of students using the flipped classroom method. The control group was six sections taught using the traditional method of lecture and homework. Each section had an average enrollment of 35 students. All students were given consent forms to participate in the student, regardless of instructional method. Only students who gave consent were included in the analysis.

All of the instructors for college algebra at the participating university during the fall 2012 semester were either full-time or adjunct instructors or graduate teaching assistants. All instructors met every week during the semester for a 45 minute course coordination meeting. A course coordinator assigned identical homework problems for all sections of both the flipped and traditional classes.

The instructor in the six traditional sections were five instructors who taught one section each and one instructor who taught two sections. Each of the instructors in the five flipped sections each taught one section.

Contents of College Algebra at the Participating University

The prerequisite for the course is a full year of modern, second year high school algebra with the grade of "C" or better. Topics covered in this course include linear, quadratic, exponential and logarithmic functions; matrices; and theory of equations.

The primary objective of the course is to develop understanding of the techniques involved in algebraic problem solving. The course is designed to fulfill the general education mathematics requirement and to prepare students to take calculus and/or statistics, should they decide to continue to study mathematics. The course syllabus with objectives is listed in Appendix A.

Procedures of the Flipped Classroom Model in College Algebra

College algebra at the participating university was flipped for five sections during the fall 2012 semester. All of these sections were included in the intervention group.

Online Videos

All of the flipped sections used the same instructional videos. For each topic in the course, two of the flipped instructors, along with the course coordinator (who did not teach College Algebra during the Fall of 2012), created online videos (vodcasts) for the course. This resulted in 30 video lessons with an average run-time of 20 minutes. The shortest lesson was 10 minutes, and the longest was just under 40 minutes. They were created using Camtasia screen capture software, a web cam, and a USB microphone. The images were captured using an Ipevo Ziggi document camera, and audio was captured with a USB microphone. Also, instead of spending class time going over exams, instructors in the flipped sections made solution videos for exams that were posted for students after the assessments were returned to the students.

Homework

All sections (traditional and flipped) were assigned the same problem sets from each section and were picked by the course coordinator. The only difference between the two types of sections was that for the traditionally taught sections, the problems were all assigned as traditional homework to be completed outside of class time. Each of these instructors had autonomy in how they accessed the completion of homework.

The flipped sections divided the assignments into two distinct categories. For each section of the text, approximately one-third of the questions were put online into the Blackboard learning management system and were given multiple choice answer sets. These were mostly questions from the concepts and vocabulary section of the assignment. These were to be completed by the students after watching the video lectures and before coming to their next class meeting. The rest of the assignment, which mostly included questions from working with formulas and applications, was done in class.

The flipped section instructors had autonomy in how they spent their class time. The main purpose was for students to complete the assignments in class, but the instructors may have supplemented this with student presentations, whole-class discussions, and peer tutoring.

Research Integrity & Compliance

The Institutional Review Board (IRB) process was submitted through the Colorado State University office of Research Integrity and Compliance Review. This study falls under the category of expedite review, where the research activity will expose participants to no more than minimal risk. Some of the issues with this study are inclusion/exclusion criteria and confidentiality of data. The IRB process was also completed at the participating university.

The inclusion criteria for the intervention group were students enrolled in the sections taught using the flipped method at the participating university. Instructors in the study received professional development on the flipped classroom model through meetings and collaborations with the researcher. The inclusion of the control group was students in the participating university who were enrolled in sections taught college algebra in the traditional lecture/homework model. Students did not know which group or method of instruction they would receive when they registered for the course. There are no exclusion criteria for students in the available population.

Measures

All subjects in the study took a pre/post algebra readiness exam and a common final exam. These tests were developed at the department level among the instructors and researcher and were aligned with the course objectives and standards. Students' scores on these tests are reported as a raw score, and these raw scores were the dependent variables in this study.

The algebra readiness exam was a ten question short answer test that assessed a student's basic knowledge of algebraic notation and simple manipulations. The exam was created by instructors at the university and has been used since spring semester of 2011. The exam is scored so that a student receives one point if the answer is correct and zero if the answer is incorrect. The exam was given to all students on the first day of classes (pretest) and then again on the last day of classes (posttest).

The common final exam was a 30 question multiple-choice exam that accessed the knowledge and skills used in College Algebra. The exam was created by the researcher and instructors at the university. The researcher created a final exam review that was given to all

instructors and students. The final exam review contained all of the topics that would be covered

on the final exam, as well as sample problems from the textbook for each topic. The researcher

then created the questions from a combination of variations on these questions with questions

from previous college algebra final exams. The exam was reviewed and revised with the course

coordinator.

Both the algebra readiness exam and the common final exam were examined for

reliability using Cronbach's Alpha. This was used to test the internal consistency reliability of

the questions on the instruments (Streiner, 2003; Morgan, Leech, Gloeckner, & Barrett, 2007).

An item-total correlation test was then performed to see if any of the questions were inconsistent

with the reliability. If the removal of any questions increased the value of alpha, then those items

were discarded and not included in the analysis. Item level data was examined to determine the

validity of all questions. If any question on the multiple-choice exam had a proportion correct (p-

value) of less than .25, then it was discarded, as most correct answers were likely due to guessing

and not representative of mathematical knowledge (Kline, 2005). Likewise, a discrimination

index (D) was calculated for each item using the extreme group method. This is done by

separating the test scores into upper and lower groups and calculating mean p-values for each

item within each group. Kline (2005) recommends using the top and bottom 27th percentiles for

the extreme groups. The 27th percentile is the value in which power is maximized in each tail

(Preacher, Rucker, MacCallum, & Nicewander, 2005). The p-values for each item are then

subtracted, giving the discrimination of the item. Items with a positive D value were retained.

However, if an item has a negative D, then his indicates an item in which those who scored

highly on the test, did poorly on this item, and those who did poorly on the test, scored high on

this item (Kline, 2005). This indicates that the item was a poor measurement of mathematical achievement and was discarded.

A pre-existing measure in this study will be students' mathematics scores on the ACT exam. The ACT is a national college admissions examination whose results are accepted by all four-year colleges and universities in the United States. The ACT Mathematics Test is a 60-question, 60-minute test designed to measure the mathematical skills students have typically acquired in courses taken by the end of 11th grade (ACT, 2012). The ACT Mathematics Test was chosen because nearly all students in the study had available ACT information. Likewise, the ACT Mathematics Test has a high reliability coefficient of .90 and has robust validity as a measure of mathematics knowledge (ACT, 2007).

Data Collection

The data collection procedure for this study is designed to address the research questions by providing data for the quantitative design.

Summer 2012

- Applied for human subject approval at Colorado State University and the participating university

- Met with College Algebra instructors to create vodcasts and plan the flipped classroom.

- Identified participants in the control and intervention groups through enrollment records.

- Obtained ACT mathematics scores from student records.

- Administered and collected algebra readiness exams from intervention and control groups.

- Collected end-of-semester scores from participating students.

Methods of Data Analysis

The quantitative data were analyzed using SPSS, a computer program common for use in statistical analysis (Field, 2005). Multiple regression and ANCOVA results are reported by giving details of the *F*-ratio, which is calculated from the sum of the squares (based on the raw final exam scores, the pre/posttest gains and sample size) and the degrees of freedom in the data. The *F*-ratio is similar to a *t*-test, but used for multiple independent variables. From the *F*-ratios, *p*-values were determined to see if there were statistically significant differences between and among the groups.

Assumptions

Parametric statistics have assumptions of normality before regression or ANCOVA can be applied. Normality of the distribution of scores was checked for skewness and kurtosis. Skewness measures the symmetry of the data, and kurtosis measures the degree to which the data clusters at the tails. Measures deviating too far from zero can imply that the data are not normally distributed. Homogeneity of variances was checked using Levene's Test (Field, 2005). If these

assumptions are severely violated, then an equivalent ordinal nonparametric such as Kruskal-Wallis will be used (Turner & Thayer, 2001).

Analysis

For the dependent variable of common final exam, a regression was used with interactions tested between gender and instructional method, and between ACT mathematics scores and instructional method. The regression was appropriate because this involved two categorical independent variables (gender and instructional method), a numerical independent variable (ACT scores), and a numerical dependent variable (common final exam scores). This design made it possible to see if there were any interaction effects between gender, ACT scores, and instructional method on final exam scores (Allison, 1999; Gliner & Morgan, 2000). In other words, this will test to see if male students respond differently to the flipped classroom than female students. Similarly, this will test whether students with higher ACT mathematics scores respond differently to the flipped classroom than students with lower ACT mathematics scores. The ACT mathematics scored were centered by subtracting each value from the overall mean.

$$y(\text{Final Exam})_i = \beta_0 + \beta_1(\text{treatment}) + \varepsilon_i$$

$$y(\text{Final Exam})_i = \beta_0 + \beta_1(\text{treatment}) + \beta_2(\text{gender}) + \varepsilon_i$$

$$y(\text{Final Exam})_i = \beta_0 + \beta_1(\text{treatment}) + \beta_2(\text{gender}) + \beta_3(\text{treatment} * \text{gender}) + \varepsilon_i$$

$$y(\text{Final Exam})_i = \beta_0 + \beta_1(\text{treatment}) + \beta_2(\text{ACT}) + \varepsilon_i$$

$$y(\text{Final Exam})_i = \beta_0 + \beta_1(\text{treatment}) + \beta_2(\text{ACT}) + \beta_3(\text{treatment} * \text{ACT}) + \varepsilon_i$$

For the dependent variable of the algebra readiness exam, an ANCOVA was used. The ANCOVA is appropriate for the algebra readiness exam because there are two between-groups independent variables (instructional method and gender), one independent variable of the algebra readiness exam posttest, and the algebra readiness exam pretest as a covariate. (Gliner & Morgan, 2000).

Simple effects analysis was used to investigate any interaction effects. This analysis looks at the effect of one independent variable at individual levels of the other independent variable (Field, 2005).

Clustering Effect

Because the sampling design puts the subjects into groups, there may be some degree of interdependence not related to the treatment (DeCoster, 2002). Specifically, students were studied within classes with different teachers. It has been shown that students, who receive instruction together in the same classroom, tend to be more similar in their achievement, regardless of instructional method (McCoach & Adelson, 2010). This may be the case in this research, and thus this study considered the effects of clustered data. Ignoring this clustering effect incorrectly reduces the standard error and may falsely increase the confidence of the outcomes and increasing the possibility of a Type I error.

To correct for this, the study utilized an intraclass correlation (ICC) to provide a measure of how similar individuals are within classrooms. If the ICC is large, this indicates a large degree of homogeneity within classrooms and/or a large degree of heterogeneity across classrooms. Both of these imply interdependence not related to the treatment. From the ICC, a design effect

(*DEFF*) was calculated where δ is the intraclass correlation, and *n* is the average size of the

cluster.

$$DEFF = 1 + \delta(n - 1)$$

The design effect (*DEFF*) is a ratio of the sampling variability for the study design

compared with the sampling variability that would be expected if the study used a single

classroom. From the *DEFF*, a *DEFT* (square root of *DEFF*) was used to calculate a scalar used

to adjust the standard errors (thus increasing the standard errors), which accounts for the

clustering and will be used in the analysis. The *DEFT* indicates the degree to which the standard

errors need to increase to account for the clustering. This will change the *t*-values and the

corresponding *p*-values, but will decrease the possibility of a Type I error.

Effect Size

In all cases, because the *p*-value and corresponding possibly statistically significant

differences are affected by the sample size, effect sizes were calculated. An effect size is a better

indication of how strong the relationship is between the independent and dependent variables

(Morgan, et al., 2007; Field, 2005).

Additional Analysis

In addition to the formal analysis of the quantitative data and the research questions,

additional analysis was performed through informal observations with the flipped classroom

instructors. From these data emerged two additional findings which are worth exploring.

First, one instructor taught both a section in traditional method and a section in the

flipped method. This particular instructor agreed to teach in the flipped classroom method only a

few weeks before the classes started and did not have any training on methods that may be effective in a flipped learning environment.

The other event that is worth analysis is that two of the instructors in the flipped intervention group had previous classroom experience with inquiry-based and cooperative learning methods. This created three groups: student taught in the traditional method, students taught in the flipped method with inquiry-based experienced instructors, and students taught in the flipped method without inquiry-based experience instructors. Therefore, an ANOVA was performed to compare the achievement of these three groups.

CHAPTER 4

RESULTS

Introduction

This quantitative research studied the effects of the flipped classroom model in college

algebra and its effect on student achievement. The common definition of a flipped classroom is

where the whole classroom/homework paradigm is "flipped". What used to be classwork (the

lecture) is done outside of class time via online videos and what used to be homework (assigned

problems) is now done in class. However, the flipped classroom definition can include any

situation in which technology is used to change the delivery of content, freeing class time for

inquiry-based and collaborative activities.

The popularity of the flipped classroom continues to expand, and there has been a

continued call for quantitative research on the effects of the flipped model on student

achievement. The purpose of this study is to investigate the mathematical achievement

differences between students in college algebra classrooms taught by instructors using the

flipped classroom method with instructors using the traditional lecture method. Gender was also

included in the analysis of outcomes to see if gender moderated the effect of the flipped model

and achievement. It has been shown that there may be gender differences in learning and

achievement of algebra (Hyde, Fenema, & Lamon, 1990; Tolar, 2007). The study also

investigated the interactions between learning environment and previous mathematics

achievement on the ACT mathematics exam.

The study is a quasi-experimental design, which is common to many studies involving

human subjects (due to the difficulty of using randomized assignment of participants to groups).

The primary dependent variable is mathematics achievement, and the primary independent

variable is learning environment.

Results and findings are presented in three main sections; instrument reliability,

quantitative analysis of the research questions, and additional analysis. Results and major

findings from the investigation are provided and organized by first looking at the effects on the

common final exam, then looking at the effects on the algebra readiness exam.

Instrument Reliability

Instrument Reliability of Common Final Exam

To access the internal consistency reliability of the questions on the common final exam,

Cronbach's Alpha was calculated. The mechanics behind Cronbach's Alpha is that is roughly

equivalent to dichotomously splitting the data in every possible permutation and computing the

correlation coefficient for each split. The average of these values is alpha (Cronbach, 1951;

Field, 2005).

The alpha for the common final exam was found to be .81. The literature suggests that for

an achievement exam, alpha should be greater than .70, in order to provide good support for

internal consistency reliability (Morgan, Leech, Gloeckner, & Barrett, 2007).

Next, an item-total correlation test was performed to see if any of the questions were

inconsistent with the reliability. There were no cases where removal of an item increased the

value of alpha, so all items were deemed reliable for the analysis. Reliability statistics for each

item can be found in Appendix B.

Questions were then checked to see if any questions had less than a 25% correct response

rate (or a mean of at least .25). If an item had a mean below .25, then less than 25% of the

questions were correct and that most correct answers were likely due to guessing and not representative of mathematical knowledge. Since all items had a mean above .25, none of the items were removed due to this criterion.

The final reliability test on the common final exam was a discrimination index for item using the extreme group method. This is done by separating the test scores into upper and lower groups and calculating mean for each item within each group. Kline (2005) recommends using the top and bottom 27th percentiles for the extreme groups. The 27th percentile is the value in which power is maximized in each tail (Preacher, Rucker, MacCallum, & Nicewander, 2005).The p-values for each item are then subtracted, giving the discrimination of the item. Since there was a total of 301 valid participants, the top and bottom 27% would be 81 participants. Descriptive statistics for each item can be found in Appendix B.

Since none of the items in the bottom 27th percentile had a higher mean than items in the top 27th percentile, none of the items were removed based on this criterion. All items in the common final exam passed tests of reliability, so all thirty items were used in the analysis.

Instrument Reliability of Algebra Readiness Exam

Table 4.1

Reliability Statistics on Algebra Readiness Exam

	N of Items	Cronbach's Alpha
Pretest	10	.67
Posttest	10	.69
Pretest	9	.68
Posttest	9	.69
Pretest	8	.70
Posttest	8	.66

The algebra readiness exam given at the beginning of the semester (pretest) had an alpha of .67. From reliability item-total statistics (Appendix B), Cronbach's Alpha was re-checked if an item was deleted. When items 1 and 2 were removed, alpha was increased. By removing these two items, alpha was increased to .70. Likewise, the same algebra readiness exam given at the end of the semester (posttest) had an alpha of .69. However, removal of items 1 and 2 lowered alpha on the posttest. Removal of item 1 on the posttest kept alpha at .69. Only the removal of item 1 increased alpha in both the pretest and the posttest. Therefore, it was decided to just remove item 1 from the analysis. Reliability data for each item can be found in Appendix B.

Next, a discrimination index reliability test was performed on the pretest and posttest of the algebra readiness exam. This is done by separating the test scores into upper and lower 27th percentile groups and calculating means for each item within each group. Since there was a total of 210 valid participants in both the pretest and posttest, the top and bottom 27th percentile would be 56 participants. The descriptive statistics of the discrimination index for each item can be found in Appendix B.

Since none of the items in the bottom 27th percentile had a higher mean than items in the top 27th percentile, none of the items were removed based on this criterion. Based on the reliability tests for the algebra readiness exam, removing item 1 only, resulted in the highest average alpha on the pretest and posttest. Thus, item 1 was removed, and items 2 through 10 were retained for the analysis.

Tests of Normality Assumptions

The skewness and kurtosis of the distribution of scores was checked for the control group and the intervention group on the common final exam and the pretest and posttest of the algebra

readiness exam. Skewness measures the symmetry of the data, and kurtosis measures the degree

to which the data clusters at the tails. Measures deviating too far from zero can imply that the

data are not normally distributed.

Table 4.2

Skewness and Kurtosis Statistics

			Skewness		Kurtosis	
			Statistic	Std.	Statistic	Std.
Group		n		Error		Error
Common Final Exam	Control	165	-.228	.189	-.745	.376
Common Final Exam	Intervention	136	-.471	.208	-.392	.413
Algebra Readiness Exam Pretest	Control	90	.313	.254	-.539	.503
Algebra Readiness Exam Pretest	Intervention	120	.302	.221	-.593	.438
Algebra Readiness Exam Posttest	Control	90	-.346	.254	-.522	.503
Algebra Readiness Exam Posttest	Intervention	120	-.484	.221	-.231	.438

The skewness statistic for all tests is not more than positive one, or less than negative

one. Morgan, Leech, Gloeckner, Barrett (2007) suggest this as an arbitrary guideline, thus the all

the data are not significantly skewed. None of the kurtosis statistics were greater than one or less

than negative one, so the literature suggests that the data can be considered normally distributed

for our analysis (Morgan, et al.,2007; Field, 2005).

Homogeneity of variances was checked using Levene's Test with SPSS. For the common

final exam, Levene's Test gave an *F*-value of .113, which implies equal variances are assumed

($F=.113$, $p = .737$). For the scores on the algebra readiness exam, Levene's Test produced an *F*-

value of .704, which implies equal variances can be assumed. ($F=.704$, $p = .402$).

Analysis of Common Final Exam

Common Final Exam and Treatment

Research Question 1 asked, "Is there an overall difference in achievement between students in the traditional environment compared to students taught using the flipped classroom method?" To analyze Research Question 1 for the common final exam, an independent samples *t*-test was run to determine whether there was a statistically significant different between the control group taught in the traditional lecture method, and the intervention group taught in the flipped method. The scores were normally distributed, as assessed by Levene's test ($F=.113$, $p=.737$).

Table 4.3

Descriptive Statistics on Common Final Exam

Group	n	Mean	Std. Deviation
Control	165	20.14	5.101
Intervention	136	21.27	5.130

The mean control group score (M=20.14, SD=5.101) was lower than the mean intervention group score (M=21.27, SD=5.130), for a mean difference of 1.133, $t(299)=1.912$, $p = .057$. This produced a *p*-value in which one should not conclude a statistically significant difference between the groups ($\alpha=.05$).

Clustering Effect

Because the sampling design puts the subjects into groups, there may be some degree of interdependence not related to the treatment (DeCoster, 2002). Specifically, students were studied within classes with different teachers. It has been shown that students, who receive instruction together in the same classroom, tend to be more similar in their achievement,

regardless of instructional method (McCoach & Adelson, 2010). To account for this, the data were analyzed using techniques of clustered and group data.

Table 4.4

Final Exam Scores by Section

	Mean	*n*	Std. Deviation
Section A	19.60	20	5.968
Section B	22.83	23	4.658
Section C	19.17	30	5.086
Section D	19.03	31	5.050
Section E	20.94	34	4.075
Section F	19.83	29	5.419
Section G*	19.14	28	5.509
Section H*	22.75	24	4.406
Section I*	20.42	33	4.981
Section J*	23.44	25	4.547
Section K*	21.04	24	5.320
Total	20.65	301	5.137

*Intervention Group Sections

An intraclass correlation (ICC) was calculated for to provide a measure of how similar individuals are within classrooms. If the ICC is large, this indicates a large degree of homogeneity within classrooms and/or a large degree of heterogeneity across classrooms. An ICC was calculated for the common final exam with each individual classroom section as the groups.

Using SPSS, an ICC of 0.060 was calculated for the common final exam with each individual classroom section as the groups. The ICC represents the likelihood that two students in the same section have the same scores relative to students chosen completely at random (Shackman, 2001). The value of 0.060 means that the students in the same classroom are 6%

more likely to have the same value than if the students were chosen at random from the entire studies population. This changes the design effect, so a design effect (*DEFF*) is calculated:

$$DEFF = 1 + \delta(n - 1)$$

Where δ is the intraclass correlation ($\delta = 0.060$) and n is the average size of the cluster ($n=27.4$).

$$DEFF = 1 + 0.060(27.4 - 1)$$

This results in a *DEFF* value of 2.58. The square root of the *DEFF* results in a *DEFT* value of 1.606. This value is then multiplied by the standard error to create and adjusted standard error. Although this increases the standard error, this decreases the possibility of a Type I error.

An independent samples *t*-test was run with the adjusted standard error to determine whether there was a statistically significant different between the control group taught in the traditional lecture method, and the intervention group taught in the flipped method. This produced a *p*-value in which one should not conclude a statistically significant difference ($\alpha=.05$) between the groups, $t(301)=1.1897$, $p=.237$.

The effect size of the treatment was calculated using Cohen's *d* and found to be $d = 0.221$. This indicated that the flipped classroom treatment had a "small" effect, or smaller than typical using Cohen's terminology, on the common final exam scores of the treatment group (Cohen, 1998).

Gender, Treatment, and Common Final Exam

Research Question 2 inquired, "Is there an interaction between gender and instructional method in regard to achievement?" In other words, do students respond differently to the flipped classroom based on their gender? To address Research Question 2 and achievement on the

common final exam, a regression was used to compare the common final exam means between gender and type of treatment.

Table 4.5

Common Final Exam Means with Treatment and Gender

Treatment	Gender	*n*	Mean	Std. Deviation
	Male	79	20.10	4.781
Control	Female	86	20.17	5.406
	Total	165	20.14	5.101
	Male	86	20.95	4.843
Intervention	Female	50	21.82	5.598
	Total	136	21.27	5.130
	Male	165	20.55	4.818
Total	Female	136	20.78	5.515
	Total	301	20.65	5.137
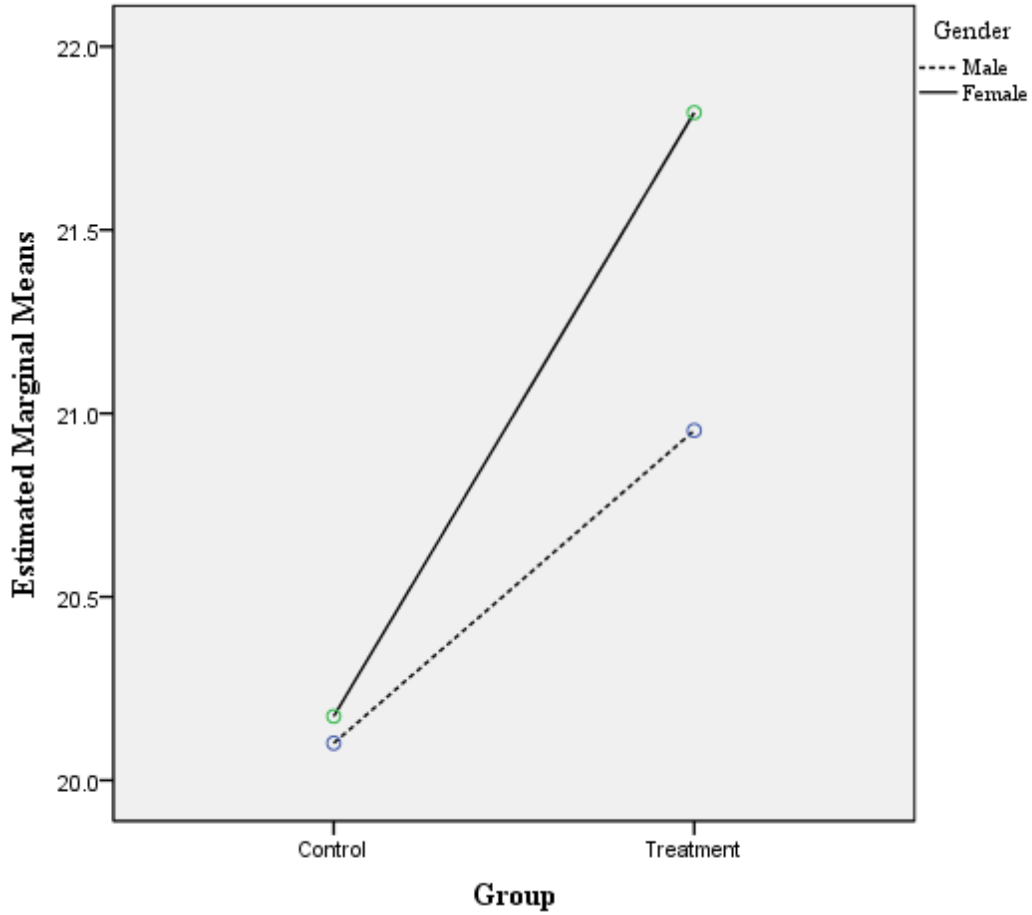
Figure 4.1. Common final exam – gender and treatment interaction

Table 4.6

Regression Coefficients for Common Final Exam, Treatment, and Gender

	B	*SE B*	*β*	Sig. (*p*)
Constant	20.762	0.303		
Gender	0.235	0.303	.046	.439
Treatment	0.624	0.303	.121	.040
Treatment*Gender	0.198	0.303	.038	.513

After removing the effects of gender, treatment has a statistically significant effect (p<.05) on the common final exam. This is a spurious relationship (Pearl, 2000) that is not seen after ACT mathematics scores are included in the regression (see Table 4.8). The regression comparing the common final exam means and gender yielded a calculated $t(297)=.776$ with $p=.439$. Since the *p*-value was greater than 0.05, this result indicated that there was no statistically significant difference between the common final exam scores of males and females. Likewise there is not a statistically significant difference ($\alpha=0.05$) in the interaction between the treatment and gender on final exam scores, $t(297)=.655$, $p=.513$. In other words, students did not respond differently to the flipped classroom, based on their gender.

ACT Math Scores, Treatment, and Common Final Exam

Research Question 3 asked, "Is there an interaction between ACT mathematics scores and instructional method in regard to achievement?" The purpose was to see if students responded differently based on their ACT mathematics score. To analyze Research Question 3 and the common final exam, a multiple regression was performed to test interactions among centered ACT mathematics scores, common final exam scores and the treatment. The multiple regression was appropriate because this includes a categorical independent variable (treatment), a numerical independent variable (ACT mathematics scores), and a numerical dependent variable (common final exam scores). This design made it possible to see if there were any interaction effects between gender, ACT mathematics scores and instructional method on final exam scores (Allison, 1999, Gliner & Morgan, 2000).

Table 4.7

Regression Coefficients for Common Final Exam, Treatment, and ACT Scores

	B	*SE B*	*β*	Sig. (*p*)
Constant	20.199	0.421		
ACT	0.338	0.138	.206	.015
Treatment	0.867	0.624	.085	.057
Treatment*ACT	-.346	.199	-.146	.084

Note: *R*=.170 for ACT; *R*=.081 for ACT*Treatment

This shows that ACT scores are a statistically significant predictor of common final exam scores with *p*=.015. There was not a statistically significant interaction between ACT scores and the treatment with regard to common final exam scores (*p*=.084). In other words, students did not respond differently to the flipped classroom based on their ACT mathematics scores.

ACT Math Scores, Gender, Treatment, and Common Final Exam

Testing for effects of the treatment when accounting for gender, gave a statistically significant effect of the treatment (p<.05). To see that this is a spurious relationship, a multiple regression analysis was employed to predict final exam scores of the treatment after accounting for gender and ACT mathematics scores. This will show if ACT mathematics scores are a confounding factor.

Table 4.8

Regression Coefficients for Common Final Exam, Treatment, Gender, and ACT Scores

	B	SE B	β	Sig. (p)
Constant	20.654	.316		
Treatment	0.447	.316	.087	.159
ACT	0.171	.100	.104	.090
Gender	0.106	.317	.021	.739

A multiple regression analysis was employed to predict final exam scores from the treatment after accounting for gender and ACT mathematics scores. The results show there is not a statistically significant effect of treatment, $t(297)=1.413$, $p=.159$, when gender and ACT mathematics scores are considered. This implies that the results in Table 4.6 showed a statistically significant effect of treatment, when only considering gender, was a spurious relationship (Pearl, 2000).

Analysis of Algebra Readiness Exam

Before the analysis of the algebra readiness exam, it should be noted that several violations occurred which affect the validity of the algebra readiness exam as a measure of achievement. For the pretest, one instructor (Section A) gave a short review before administering the exam. Also, there was confusion among the sections about the purpose of the exam. Some students were led to believe that a poor performance on the pretest would result in their demotion to a lower level course.

The posttest was given immediately before the common final exam, and there was misunderstanding among the students and sections about the purpose of the posttest and if it would count towards a students' final grade. The literature suggests that for an achievement

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exam, Cronbach's Alpha should be greater than .70 in order to provide good support for internal consistency reliability (Streiner, 2003; Morgan, Leech, Gloeckner, & Barrett, 2007). The algebra readiness exam had alpha less than .70 (α=.69). Although the algebra readiness exam will be analyzed, these violations affect the integrity of this measure and results should be used with caution.

Algebra Readiness Exam and Treatment

To analyze Research Question 1 for the algebra readiness exam an ANCOVA was executed to test the effects of the treatment on students' performance on the algebra readiness exam. The algebra readiness exam posttest was the dependent variable and the algebra readiness exam pretest was the covariant. Because removal of question 1 from the algebra readiness exam resulted in a larger Cronbach's Alpha, question 1 was removed from the analysis. Homogeneity of variances was checked using Levene's Test with SPSS. Levene's Test produced an *F*-value of .704, which implies equal variances can be assumed. (*F*=.704, *p* = .402).

Table 4.9

Descriptive Statistics on Algebra Readiness Exam Pretest

Group	n	Mean	Std. Deviation
Control	90	4.19	2.292
Intervention	120	4.27	2.198
Total	210	4.23	2.233

Table 4.10

Descriptive Statistics on Algebra Readiness Exam Posttest

Group	n	Mean	Std. Deviation
Control	90	5.29	2.333
Intervention	120	5.63	2.200
Total	210	5.48	2.259

Table 4.11

ANCOVA Test of Algebra Readiness Exam

Source	Sum of Squares	df	Mean Square	F	Sig.
Pretest	377.908	1	377.908	114.584	.000
Treatment	4.299	1	4.299	1.303	.255
Error	682.706	207	3.298		

The ANCOVA test comparing the algebra readiness exam means yielded a calculated $F(1,208)=1.303$ with $p=.255$. Since the p-value was greater than 0.05, this result indicated that there was no statistically significant difference on algebra readiness exam scores between the treatment and control groups. The effect size of the treatment was calculated using Cohen's d with $d = 0.16$.

Gender, Treatment, and Algebra Readiness Exam

To analyze Research Question 2 for the algebra readiness exam, the data were analyzed to see if there was an interaction of gender and treatment with achievement on the algebra readiness exam. An ANCOVA was performed to investigate the data by entering the pretest algebra readiness exam scores as the covariate, the posttest algebra readiness exam scores as the dependent variable, and student gender and treatment as independent variables.

Table 4.12

Descriptive Statistics for Gender, Treatment, Pretest, and Posttest

	Treatment Group	Gender	Mean	Std. Deviation	N
Pretest	Control	Male	4.2821	2.15148	39
		Female	4.1176	2.41369	51
		Total	4.1889	2.29261	90
	Intervention	Male	4.2468	2.25456	77
		Female	4.3023	2.08777	43
		Total	4.2667	2.18756	120
	Total	Male	4.2586	2.21112	116
		Female	4.2021	2.26036	94
		Total	4.2333	2.22810	210
Posttest	Control	Male	4.8974	2.37082	39
		Female	5.5882	2.28190	51
		Total	5.2889	2.33317	90
	Intervention	Male	5.4286	2.24446	77
		Female	5.9767	2.09862	43
		Total	5.6250	2.20032	120
	Total	Male	5.2500	2.29129	116
		Female	5.7660	2.19690	94
		Total	5.4810	2.25887	210

Table 4.13

ANCOVA *Tests of Gender, Treatment, Pretest, and Posttest*

Source	Sum of Squares	df	Mean Square	F	Sig.
Pretest	378.808	1	378.808	155.113	.000
Treatment	8.942	1	8.942	2.718	.101
Gender	22.069	1	22.069	6.708	.010
Treatment * Gender	1.083	1	1.083	.329	.567
Error(Time)	674.487	205	3.290		

There was a statistically significant difference between the performance on the algebra

readiness exam with regard to gender, regardless of treatment, with females achieving higher

than males $F(1,205)=6.708$, $p=.010$. There was not a statistically significant interaction, $F(1,205)=0.329$, $p=.567$, among the algebra readiness exam, gender, and the treatment. In other words, students did not respond differently to the flipped classroom based on their gender.

Additional Analysis

In addition to the formal analysis of the quantitative data and the research questions, additional analysis was performed through informal observations with the flipped classroom instructors. From these data emerged two additional findings which are worth exploring.

Same Instructor Taught Both Methods

One instructor taught both a section in traditional method (Section C) and a section in the flipped method (Section G). This particular instructor agreed to teach in the flipped classroom method only a few weeks before the classes started and did not have any training on methods that may be effective in a flipped learning environment.

Table 4.14

Final Exam Scores by Section

	Mean	n	Std. Deviation
Section C	19.17	30	5.086
Section G*	19.14	28	5.509

*Intervention Group

An independent samples *t*-test of the common final exam scores yielded $t(56)=0.022$, $p = .983$. This shows there is not a statistically significant difference in scores ($\alpha=.05$) between the control group and the treatment group. A calculation of effect size from these data gives a negligible Cohen's $d=-0.01$. The implications of this is discussed in the Conclusions section.

Instructors with Inquiry-Based Learning Classroom Experience

The other event that is worth analysis is that two of the instructors in the flipped intervention group had classroom experience with inquiry-based and cooperative learning methods (Sections H & J). Therefore, an ANOVA was performed to compare their student achievement with student achievement in the other flipped intervention sections and with the traditionally taught sections. For this analysis, three groups were created. The first group is all sections that were taught in the traditional method. The second group is sections taught in the flipped method, where the instructor did not have experience with inquiry-based or cooperative learning methods. The third group was sections taught in the flipped method with instructors who had classroom experience with inquiry-based and cooperative teaching methods.

Table 4.15

Descriptive Statistics on Common Final Exam Score

Group	*n*	Mean	Std. Deviation
Traditional	165	20.14	5.101
Flipped (No Inquiry)	88	20.25	5.196
Flipped (Inquiry)	48	23.15	4.482

Table 4.16

ANOVA Common Final Exam Scores with Three Groups

	Sum of Squares	*df*	Mean Square	*F*	Sig.
Between Groups	352.157	2	176.079	6.937	.001
Within Groups	7564.215	298	25.383		
Total	7916.372	300			

The results of the ANOVA show there is statistically significant difference between these groups, $F(2,298)=6.937$, $p<.05$. To see where this difference resides, post hoc comparison tests were used using Tukey HSD.

Table 4.17

Post Hoc Multiple Comparisons of Common Final Exam Scores

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Flipped (No Inq.)	Traditional	.102	.668	.987	-1.47	1.67
Flipped (Inq.)	Traditional	2.963[*]	.820	.001	1.03	4.89
Flipped (Inq.)	Flipped (No Inq.)	2.861[*]	.900	.005	.74	4.98

* The mean difference is significant at the 0.05 level.

Flipped (No Inq.)-Traditional   Flipped (Inq.) – Traditional   Flipped (Inq.) - Flipped (No Inq.)
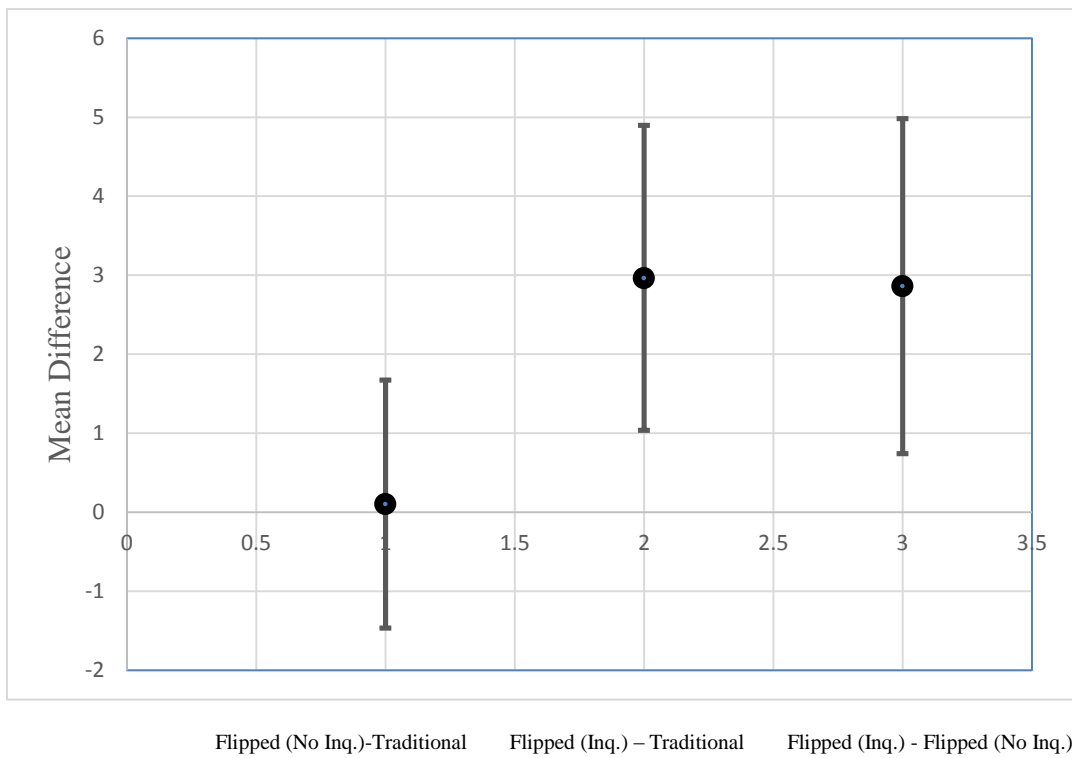
Figure 4.2. Confidence intervals and mean difference common final exam scores

Post hoc Tukey HSD Tests indicate that the traditional and flipped (inquiry) groups had a statistically significant difference on common final exam sores ($p<.05$) with a calculated Cohen's d=0.61. Likewise, there were also statistically significant differences on the common final exam score between the flipped sections taught by teachers with and without inquiry-based teaching experience ($p<.05$). The effect size of having inquiry-based experienced teachers was a Cohen's d=0.59. However, there was no statistically significant difference when comparing the traditional sections with flipped sections taught by instructors who did not have inquiry-based teaching experience (p=.987). This resulted in a negligible effect size of Cohen's d=0.02. The implications of this and all calculated effect sizes will be interpreted in the Conclusions section.

CHAPTER 5

DISCUSSION

Introduction

This research studied use of the flipped classroom in college algebra and its effect on student achievement. In the flipped class sections, teachers used online videos of lectures, with students viewing them outside of class time. In theory, but not necessarily practice, students would then work in class on inquiry-based and collaborative group work assignments which include what is traditionally thought of as homework. The accessible population in this study were all students at the university taking College Algebra during the fall 2012 semester. Participants in the intervention group were five sections of students using the flipped classroom method. The control group was six sections taught using the traditional method of lecture and homework. The dependent variable used to test student achievement was a common final exam and a pre/post algebra readiness exam. This study may contribute to positive change in education, as it provides a researched-based foundation drawn from a university mathematics setting that assesses the benefits of technology for student achievement. This chapter will discuss and summarize the results and deliberate the limitations of the study. The implications for teaching and recommendations for practice will be explored, followed by recommendations for further research.

Summary and Discussion

Common Final Exam

The main instrument used to test the research questions was a common final exam that consisted of 30 multiple choice questions. It was developed by the researcher and the course coordinator. Cronbach's Alpha showed that the instrument had good internal consistency reliability. Likewise the instrument passed a discrimination index for each item using the extreme groups method. The scores from the common final exam were deemed to be normally distributed by exploring skewness and kurtosis and Levene's Test results implied that there was homogeneity of variances.

For Research Question 1, the results showed that the mean of the sections taught in the traditional method group scores were slightly lower than the mean of the sections taught using flipped methods. This produced a *p*-value in which one should not conclude a statistically significant difference between the groups. The effect size of the treatment was calculated using Cohen's *d* and found to be $d = 0.221$. This indicated that the flipped classroom treatment had a "small" effect, using Cohen's terminology, on the common final exam scores of the treatment group (Cohen, 1998).

Research Question 2 addressed the effects of gender and the treatment on student achievement. Results showed there was not a statistically significant difference in the interaction between the treatment and gender on common final exam scores. This implies that the different instructional methods did not have a difference in their benefit for males or females and their mathematical achievement.

Research Question 3 asked if there is an interaction between ACT mathematics scores and instructional method in regard to achievement. Results showed that ACT mathematics scores

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are a statistically significant predictor of common final exam scores. However, there was not a statistically significant interaction between ACT mathematics scores and the treatment with regard to common final exam scores. This suggest that although students who had higher ACT math scores performed better on the common final exam, there was no difference in how students responded to the treatment with different ACT mathematics scores.

Algebra Readiness Exam

As mentioned in the previous chapter, the algebra readiness exam given as a pretest at the beginning of the semester, and as a posttest at the end of the semester, had several violations of validity. Although the algebra readiness exam was analyzed, these violations severely affect the integrity of this measure, and results will not be used in the summary or discussion of implications of this research.

Additional Analysis

From the analysis of the research questions, two events emerged that were further analyzed. One instructor taught both a section in traditional method and a section in the flipped method. This particular instructor agreed to teach in the flipped classroom method only a few weeks before the classes started and did not have any training on methods that may be effective in a flipped learning environment, such as inquiry or cooperative-based learning. The mean scores of the students of this instructor on the common final exam for the traditional section and the flipped section were effectively identical.

This instructor did not have any training on the tenets of flipped classroom. In an observation of the class, the instructor announced, "This is the flipped class, so you watched the

lecture video and you will work on homework in class. I will be up here (at the front of the class), if you have questions." This section did not receive any of the benefits of flipped classroom model which is to create a dynamic, inquiry-based learning environment. The students did not have the advantage of working problems in collaborative groups. In essence, the class became an online course with videos to watch outside of class, and class mostly became scheduled office hours. However, it is encouraging that even though the flipped classroom was done "wrong", the student achievement on the common final exam was no worse than the achievement on the common final exam in the same instructors traditionally taught, lecture-based section.

Even though all of the instructors teaching in the flipped sections were told the purpose and given advice on how to teach a flipped classroom, only two instructors had previous classroom experience with teaching in an inquiry-based and cooperative learning mathematics classroom. Both of these instructors taught flipped sections. It was purposely given that all instructors had autonomy in how they spent their class time and how they accessed the completion of homework (both online and paper). Therefore, even though the instructors who were inexperienced in inquiry-based learning were aware that this might be beneficial, a lack of training prevented them from having an active classroom, and students simply worked on homework in class. For this reason, three groups were created. The first group was all sections that were taught in the traditional method. The second group was sections taught in the flipped method, where the instructor did not have experience with inquiry-based or cooperative learning methods. The third group was sections taught in the flipped method with instructors who had classroom experience with inquiry-based and cooperative teaching methods.

The students in the sections taught by instructors with classroom experience with inquiry-based learning in the flipped sections scored significantly higher than the other two groups. The effect size was a Cohen's d=0.59 when compared to the other flipped sections and was a Cohen's d=0.61 when compared to the traditional lecture-based sections. This indicated that having the flipped sections taught by instructors with inquiry-based classroom experience treatment had a "medium" effect, using Cohen's terminology, on the common final exam scores (Cohen, 1998).

However, there was a negligible effect size (Cohen's d=0.02) when comparing the flipped sections taught by instructors without inquiry-based learning experience and all traditional sections. Thus, at worst, the flipped section students performed as well as the traditional sections, regardless of teacher experience. This begs the question of whether the teachers with inquiry-based experience would have seen significantly higher exam scores if they had taught in the traditional section. Although unsupported by data, the researcher argues that this would not be the case because the course is very content heavy, and class time would have had to be spent on lecture covering the content of the course. If the instructors had spent substantial class time on inquiry-based and collaborative problem-solving, there would not have been time to cover the content of the course. However, in the flipped model, by having the mathematical content explained through online video instruction, the instructors were able to have sufficient face-to-face time to utilize collaborative and inquiry-based instruction.

This research compares favorably with recent research on flipped learning in higher education. These studies have shown that the flipped model improved student performance and perceptions (Pierce & Fox, 2012; Moravec, et al., 2010; Love, et al., 2013). One common theme is all of these studies is that one of the most important aspects of the flipped model is not the videos, but the changed use of the face-to-face class time, which increased students' achievement

in the courses. This study suggests having instructors use inquiry-based or cooperative learning had higher achievement than courses taught in the traditional method.

There are several cases in which teachers have "flipped" their classrooms by providing lectures on video, but their face-to-face time has just become group office hours. This version of the flipped classroom has not been proven effective, (Makice, 2012; Waddell, 2012). Likewise, Strayer (2007) reported dissatisfaction in flipping a college level introductory course. This was attributed to tasks not being clearly defined, and students being confused over the purpose of the changes. This research study also found that in flipped sections in which the instructors were not experienced with non-lecture based learning did not score higher than sections taught in the traditional method.

This research shows that the flipped classroom model of teaching produces no harm regardless of instructor methods, but may have potential benefits when combined with inquiry or cooperative-based learning practices.

Limitations

The most significant limitation is that the study was a quasi-experimental design. Except for one instructor who taught both a section in both the control and intervention sections, different teachers taught different sections in both the traditional, control group sections and in the intervention, flipped sections. Thus, there may be teacher variables outside the intervention which contributed to group differences.

As per university policy, all instructors were given autonomy in how they ran their classes. The constants were that all sections had 200 minutes of face-to-face class time per week, the course coordinator mandated identical homework problems, and the material to be covered

was consistent (see Appendix A). However, individual instructors had differing policies in how they collected and assessed homework. Even among the flipped section instructors, there was no consistency in how the online homework that complimented the video lectures was assessed.

For the flipped sections, there was no explicit direction on what to do in class. Though it was recommended by the researcher to use class time as an active session where students would work collaboratively in groups, have students' present mathematics to the class or in their groups, have active whole-discussions (not lectures), and other tenets of a dynamic learning space, many times the face-to-face time was simply having student work on homework in class. It is presumed that a lack of teacher training of these classroom methods was the main reason for not implementing these inquiry-based and collaborative learning techniques.

There was also inconsistency among the online instructional videos. The videos were created by the course coordinator, who did not teach any section, and two of the flipped classroom instructors. There was a mood among students in the flipped sections that they did not like having the instructional videos rotated among the instructors and did not like the contrasting teaching styles of the instructors.

Finally, the data collected and used in the analysis was performance on a common finale exam taken one time at the end of the semester. This single measure may not reflect a student's overall mathematics ability or retention of the material of college algebra. Furthermore, the data collected are from one medium sized state university and may not be completely applicable to similar interventions in different demographic environments.

Implications for Practice

With the proliferation of Internet technology, virtual communications and learning management systems, many college and university instructors are interested in a flipped

classroom. Likewise, recent technologies have made the process of producing online video lectures particularly easy. Only a few years ago, making videos and uploading them to a place where students can access them took a certain amount of technical savvy. Now we have programs that will easily allow instructors to hit record, save, and paste the link to their videos. Likewise, a plethora of online instructional videos are becoming increasingly available to instructors and students that allow them to carefully curate pre-made instructional videos.

Therefore, the main hurdle for the flipped classroom model is not necessarily the instructional video lectures, but how to spend class time. The Flipped Learning Network (2014) recently released a formal definition of flipped learning:

> Flipped Learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space in transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter. (p. 1)

Lately, there has been a movement among flipped learning leaders to distinguish between a flipped classroom and flipped learning. This research explored a flipped classroom method which is simplistically classwork at home (the lecture) and homework in class. However, it was shown in this research that instructors who employed the tenets of flipped learning had the highest student achievement.

The implications for teaching is that flipped learning model is becoming increasingly popular in higher education, and universities and colleges must be prepared. The influential *Horizon Report: 2014 Higher Education* recently selected flipped classrooms as one of their near-term technologies that are expected to achieve widespread adoption in one year or less (Johnson, Adams Becker, Estrada, & Freeman, 2014).

This research showed that simply having instructors flip their classrooms without properly preparing activities and outcomes to occur during face-to-face class time will not result in higher student achievement.

By combining the results of this research with the literature review and the conceptual framework for a flipped classroom, the researcher offers several recommendations for educators interested in implementing flipped learning methods.

The short online homework assignments were mostly created to make sure that students had watched the online videos before attending class. However, some students would simply state that the videos were not playing, so they could not complete the online homework, or several of the flipped instructors did not even assign the online homework problems. The recommendation is to make an assignment or assessment that ensures students have watched and absorbed the content of the video lectures. This could be done with online homework, quizzes at the beginning of class, or by checking a student's notes. Technology is now making it easy for instructors to tell when and for how long a student was engaged in a video, and it is possible to embed quizzes directly into videos.

The most important aspect of teaching in a flipped learning model requires teachers to not just present lectures on videos and open class time for working on homework, but must use face-to-face class time for dynamic and active, inquiry-based, and cooperative learning opportunities for their students. This is not a trivial task; instructors must be trained in these classroom methods. To teach a subject in lecture method, the teacher only needs to be content expert at a level to disseminate the information. However, for a flipped classroom, the teacher must be not only a content expert, but an expert in classroom and facilitation management. To teach in this

model, instructors mush relinquish a degree of control when they make the transition from "sage on the stage" to "guide on the side" of flipped learning.

Recommendations for Further Research

The flipped learning method is gaining popularity and interest an exponential rate both at the K-12 level and in higher education. There is a definite need for further research on the topic both in quantitative and qualitative studies.

For quantitative studies, it would be ideal to create intervention designs with common assessments of student achievement and have a large group of instructors teach at least one section in the traditional method and at least one section in the flipped learning method during the same semester. This would mitigate the teacher effect and allow the research to see the instructional differences among the instructors and how they affect the results.

Likewise, qualitative studies could be done that show best practices of creation and design of flipped learning courses. Researchers could study the aspects of higher education courses that work well for flipped learning and note the inherent pitfalls, both with instructor and student observations and case-studies.

The literature shows the effectiveness of both constructivist and cooperative learning in undergraduate STEM education (Freeman, et al., 2014; Springer, Stanne, & Donovan, 1999). Research could be done that compares this "traditional" constructivist and cooperative learning in undergraduate courses with a flipped learning model that combines constructivist and cooperative leaning with online video instruction. For such a study, instructors would need to be effectively trained in inquiry-based teaching methods, and this could determine if the flipped learning model has effects beyond the traditional inquiry-based methods.

Conclusion

This research contributes to the growing scholarly research on the flipped classroom and supports the tenet that the flipped learning model can be successful in higher education. University policy of allowing autonomy in how instructors taught their sections may have been a strong confounding variable in the effectiveness of the flipped classroom method, and the results of this study should be used with caution. However, it shows that untrained instructors in the flipped sections had students who performed at least as well as students in traditional sections. Furthermore, instructors who are skilled at inquiry-based and cooperative learning had the most success with the flipped classroom model.

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APPENDIX A: MATH 124 MATERIALS

Course Syllabus for Flipped Sections

College Algebra (4 credits)

Office Hours:
MWF 1:10 – 2pm. If you cannot make this time, please email me and we'll set up a time. I am more than willing to meet around your schedule.

Prerequisite: Full year of modern, second year high school algebra with the grade of "C" or better.

Course Description: Topics covered in this course include linear, quadratic, exponential and logarithmic functions; matrices; theory of equations.

Required Materials:

- Coburn, J. (2009). *College Algebra, 2nd ed.* New York: McGraw-Hill, notebook, pencils

Recommended Materials:
- Graphing Calculator (Instructor will be using a TI-84).
  - Sharing of calculators during quizzes or exams will not be permitted.
  - Some quizzes and exams are "no-calculator".

Come to class each period ready to do active mathematics. You will need a notebook, several pencils, a calculating device (graphing calculator or Internet access).

Course Requirements

This course is being taught in a method known as "flipped learning" or the "flipped classroom". It is called the flipped class model because the whole classroom/homework paradigm is "flipped". In its simplest terms, what used to be classwork (the lecture) is done at home via teacher-created videos and what used to be homework (assigned problems) is now done in class.

Each section of the text has an online video made by an experienced UNC mathematics instructor. There will also be optional videos for exam review and homework solutions.

- For each section it is your responsibility to watch and take notes on the online video instruction prior to coming to class.
- For each section there is a short online homework assignment on Blackboard that is to

be done prior to class.
- Instead of lecture, classtime will be spent on activities and the more difficult homework problems.
    - You will have the opportunity to work in groups and with partners.
    - Students will be expected to present solutions to their groups or the entire class.
    - Because of the active nature of classtime, **attendance is mandatory**. If you have an excused absence please contact your instructor as soon as possible.
- Every Friday will be a quiz on the current week's videos and in-class material. It is your responsibility to be prepared for quizzes. Your lowest quiz score will be dropped from your final grade.

Grading Allotment:

    10% Attendance
    30% Three in-class exams
    20% Comprehensive Final Exam
    15% Quizzes
    10% Homework
    15% Projects, Activities and Participation

Your homework grade will be a mix of the online homework and occasional collected homework. More details about projects will be given later in the semester.

Grading Scale:

A	90.0-100%
B	80.0-89.9%
C	70.0-79.9%
D	60.0-69.9%
F	59.9% and below

Tests and Final Exam: All will be in-class exams. You will not be allowed to make up a missed test, unless you have a university authorized absence.

Final exam: Tuesday, December 11th, 2012

Important Dates:
- August 31, 2012: Last day to add a course
- September 10, 2012: Last day to drop a course
- September 3, 2012: Labor Day - No Classes
- October 19, 2012: Last day to withdraw from course
- November 21-23, 2012: Thanksgiving Break – No Classes

Portable Electronic Devices: Please extend courtesy to your instructor and fellow students by turning off the audio of your portable electronic devices such as: cell phones, iPods and laptops. You may use these devices in class only for relevant learning of College Algebra. Text-messaging, Facebook, etc., in class is not allowed and will be considered a disruption.

If you know that you may need to accept an emergency phone call during class or if you have children in childcare or school, please let the instructor know. If you need to take a phone call during class, please step out of the classroom while you complete your call. Thank you for your cooperation.

Tutoring Services: There are two resources you can seek out for tutoring:
   o The Math Lab, located in Ross Hall Room 1250, provides drop-in tutoring services for MATH 124. Available times will be posted on the door and on Blackboard.
   o Tutoring is also available at the Center for Human Enrichment in the basement of Michener. Appointments are necessary for each one hour appointment. To schedule an appointment, you need to go to the center. Sessions with a tutor are provided for one hour. An appointment has to be made for each tutoring session.

Accommodations: Any student requesting disability accommodation for this class must inform the instructor giving appropriate notice. Students are encouraged to contact Disability Support Services at (970) 351-2289 to certify documentation of disability and to ensure appropriate accommodations are implemented in a timely manner.

Policies: Consult your student handbook for university policies on student conduct in the classroom, cheating, plagiarism, and other academic expectations; the handbook is available through the website for the Dean of Students Office: http://www.unco.edu/dos. You are expected to attend class and take responsibility for your own learning. UNC's policies and recommendations for academic misconduct will be followed.

Honor Code: All members of the University of Northern Colorado community are entrusted with the responsibility to uphold and promote five fundamental values: Honesty, Trust, Respect, Fairness, and Responsibility. These core elements foster an atmosphere, inside and outside of the classroom, which serves as a foundation and guides the UNC community's academic, professional, and personal growth. Endorsement of these core elements by students, faculty, staff, administration, and trustees strengthens the integrity and value of our academic climate.

Changes
The instructor reserves the right to amend, adjust, or otherwise modify the outline and syllabus at any time during the course. Changes will be announced in class and posted online on Blackboard. The new syllabus will be available under the 'Syllabus' link, and I will post an announcement on Blackboard to make everyone aware of the changes.

Course Objectives: The primary objective of the course is to develop understanding of the techniques involved in algebraic problem solving. The course is designed to fulfill the general education mathematics requirement and to prepare students to take calculus and/or statistics, should they decide to continue to study mathematics. General Education Council Expectations met by Math 124:

- The student will demonstrate proficiency in the use of algebra to structure their understanding of and investigate questions in the world around them.
- The student will demonstrate proficiency in treating algebraic content at an appropriate level.
- The student will demonstrate competence in the use of numerical, graphical, and functional representations of algebra topics.
- The student will demonstrate the ability to interpret data, analyze graphical information, and communicate solutions in written and oral form.
- The student will demonstrate proficiency in the use of algebra to formulate and solve problems.
- The student will demonstrate proficiency in using technology such as handheld calculators and computers to support their use of algebra.

Math 124 Final Exam   Name_____

This exam consists of 30 multiple-choice problems and the same algebra readiness exam you took at the beginning of the semester. You have 2.5 hours to complete the exam. Some questions will take longer and are more difficult than others, so do not spend too much time on a single problem. Balance your time wisely. Check your answers carefully.

The last two pages are the same Algebra Readiness exam you took at the beginning of the semester. Please put your name on this and complete. It is up to each instructor how this will count towards your grade.

Calculators and electronic devices are NOT allowed. You will need a #2 pencil and fill in your answers on the accompanying Scantron™ sheet. **Be sure to mark your TEST VERSION on the Scantron™ sheet.**

Be sure to put your PDID on your Scantron™ sheet.

VERSION C

<u>Formulas</u>

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

Distance Formula

Given any line segment with endpoints $P_1 = (x_1, y_1)$ and $P_2 = (x_2, y_2)$, the midpoint M is given by

$$M: \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2} \right)$$

Midpoint formula

$$m = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

Slope of Line

The Difference Quotient

For a function $f(x)$ and constant $h \neq 0$, if f is smooth and continuous on the interval containing x and $x + h$,

$$\frac{f(x + h) - f(x)}{h}$$

is the difference quotient for f.

Even Functions

A function f is an *even function* if and only if, for each point (x, y) on the graph of f, the point $(-x, y)$ is also on the graph. *In function notation*

$$f(-x) = f(x)$$

Odd Functions

A function f is an *odd function* if and only if, for each point (x, y) on the graph of f, the point $(-x, -y)$ is also on the graph. *In function notation*

$$f(-x) = -f(x)$$

Logarithmic Properties

$$y = \log_b x \Leftrightarrow b^y = x \qquad \log_b b = 1 \qquad \log_b 1 = 0$$

$$\log_b b^x = x \qquad b^{\log_b x} = x \qquad \log_c x = \frac{\log_b x}{\log_b c}$$

$$\log_b MN = \log_b M + \log_b N \qquad \log_b \frac{M}{N} = \log_b M - \log_b N \qquad \log_b M^P = P \cdot \log_b M$$

$$A = P \left(1 + \frac{r}{n} \right)^{nt}$$

Interest Compounded n Times per Year

$$A = Pe^{rt}$$

Interest Compounded Continuously

Circles

circle with center
at (h, k)

k

(h, k)

central
circle

$(x - h)^2 + (y - k)^2 = r^2$

(x, y)

r

$(0, 0)$

h

x

$x^2 + y^2 = r^2$

Ellipses

$(h, k + b)$

ellipse with center
at (h, k), $a > b$

k

$(h - a, k)$

(h, k)

$(h + a, k)$

$(h, k - b)$

$\frac{(x - h)^2}{a^2} + \frac{(y - k)^2}{b^2} = 1$

central
ellipse

$(0, b)$

$(-a, 0)$ $(-c, 0)$

$(c, 0)$ $(a, 0)$

h

x

If $a < b$, the ellipse
is oriented vertically.

$(0, -b)$

$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$

$c^2 = |a^2 - b^2|$

$x^2 = 4py$
vertical parabola
focus $(0, p)$
directrix $y = -p$

y

$(0, p)$

$y = -p$

x

$p > 0$

y

$p > 0$

$(p, 0)$

x

$x = -p$

$y^2 = 4px$
horizontal parabola
focus $(p, 0)$
directrix $x = -p$

Parabola

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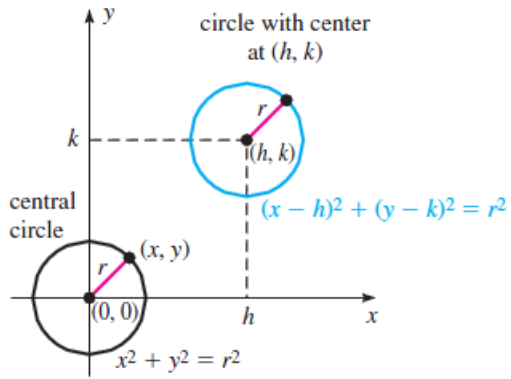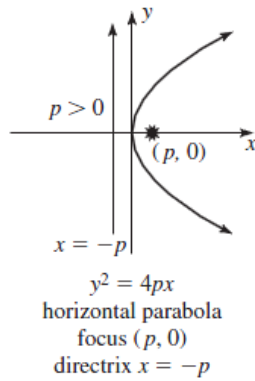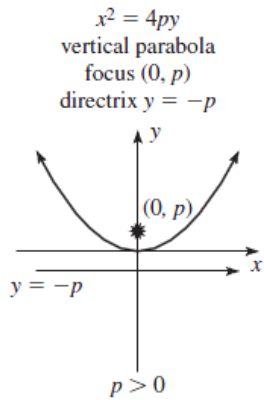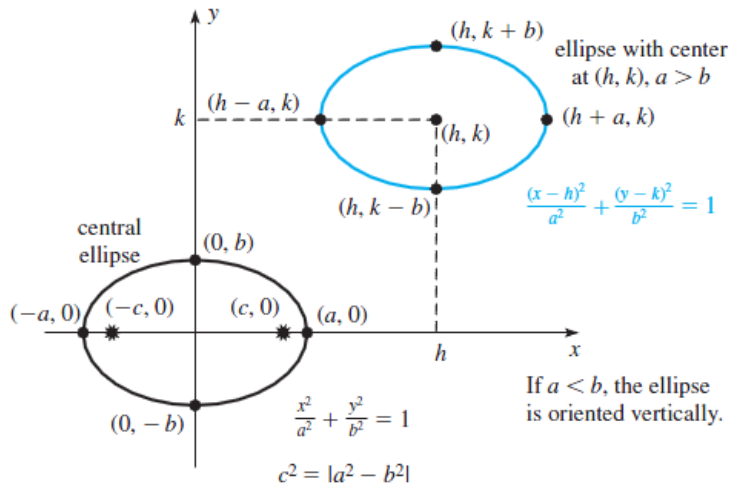
Question 1-4 refer to the linear equation $4x - 3y = 24$

1. What is the slope of this line?

   a) $\frac{4}{3}$

   b) $\frac{-3}{4}$

   c) $\frac{5}{3}$

   d) -3

   e) 4

2. What is the y-intercept of this line?

   a) -6

   b) 6

   c) -8

   d) 8

   e) 0

3. What would be equation of a line parallel to $4x - 3y = 24$ going through the point (3,6)?

   a) $y = \frac{4}{3}x + 8$

   b) $y = 4x - 8$

   c) $y = \frac{-4}{3}x + 2$

   d) $y = \frac{4}{3}x + 2$

   e) $y = 4x + 3$

4. What would be the equation of a line perpendicular to $4x - 3y = 24$ going through the point (0,0)?

   a) $y = \frac{4}{3}x - 5$

   b) $y = \frac{4}{3}x - 3$

   c) $y = \frac{4}{3}x$

   d) $y = \frac{-3}{4}x - 5$

   e) $y = \frac{-3}{4}x$

5. Simplify $(3 + 4i)(3 - 4i)$

    a) 12
    b) 25
    c) $9 - 16i$
    d) $9 + 16i$
    e) $9 + 24i$

6. $i^{13} =$

    a) 1
    b) -1
    c) i
    d) $-i$
    e) 0

7. Given $f(x) = \sqrt{2x - 5}$ and $g(x) = 2x - 3$. Determine $(f \circ g)(x)$.

    a) $\sqrt{4x - 1}$
    b) $\sqrt{4x - 11}$
    c) $\sqrt{4x^2 - 1}$
    d) $\sqrt{4x + 5}$
    e) $\sqrt{2x - 3}$

8. Given the points (3,-1) and (6,0), find the equation of the line that goes through the two points.

    a) $y = \frac{1}{3}x - 4$
    b) $y = \frac{2}{3}x - 3$
    c) $y = 3x - 4$
    d) $y = \frac{1}{3}x - 2$
    e) $y = \frac{1}{3}x - 3$

Use the quadratic equation $f(x) = x^2 - 8x + 12 = 0$ to answer question 9-12.

9. Describe the end behavior.

   a) down/up
   b) up/down
   c) up/up
   d) down/down
   e) not a function

10. Identify the vertex.

   a) (6,2)
   b) (2,6)
   c) (2,4)
   d) (2,10)
   e) (4,-4)

11. Identify the zeros or roots.

   a) $x = 6$ and $x = 2$

   b) $x = 5$ and $x = 2$

   c) $x = 6$ and $x = 3$

   d) $x = 5$ and $x = 3$

   e) $x = 7$ and $x = 3$

12. Identify the y-intercept.

   a) (12,0)
   b) (0, 12)
   c) (0,-12)
   d) (-12,0)
   e) (0,0)

13. Which of the following is the equation of a circle with center at (0,5) and a radius of 4?

a) $y = x^2 + (y + 5)^2 = 2$
b) $y = x^2 + (y - 5)^2 = 8$
c) $y = x^2 + (y - 5)^2 = 16$
d) $y = x^2 + (y + 5)^2 = 4$
e) $y = x^2 + (y - 5)^2 = 8$

14. What is distance between the points (-2,0) and (6,6)?

a) $\sqrt{10}$
b) $\sqrt{14}$
c) 10
d) 8
e) 6

15. The following equation graphs a circle. What is the radius of this circle?
$$x^2 + y^2 + 4x - 6y = 3$$

a) 16
b) 9
c) 4
d) 3
e) no solution

16. $f(x) = \begin{cases} x + 1, & x < 3 \\ x + 5, & x \geq 3 \end{cases}$, evaluate $f(5)$

a) 6
b) 5
c) 3
d) 10
e) 12

17. Which of the following describes the transformation of the toolbox function
$$f(x) = -(x + 3)^2 + 8$$

   a) It's $f(x) = x^2$ but shifted up 8 and left 3.
   b) It's $f(x) = x^2$ but flipped over the x-axis, shifted up 8 and left 3.
   c) It's $f(x) = x^2$ but flipped over the x-axis, shifted up 8 and right 3.
   d) It's $f(x) = x^2$ but flipped over the x-axis, shifted up 8 and right 8.
   e) It's $f(x) = x^2$ but shifted up 3 and right 8.

18. Compute the difference quotient for the function $f(x) = x^2 + 6$.

   a) $2x + 6$
   b) $2x + h$
   c) $2x + 6h$
   d) $2x + h + 6$
   e) $2x - 6$

19. What is the remainder when you divide $(x^3 + 2x^2 - 7x + 6)$ by $(x + 3)$?

   a) -18
   b) -9
   c) 0
   d) 9
   e) 18

20. In interval notation, what is the solution to the inequality $x^2 - x \geq 12$?

   a) [-4,3]
   b) [-3,4]
   c) $(-\infty, -3] \cup [4, \infty)$
   d) $(-\infty, 3] \cup [4, \infty)$
   e) [3,4]

21. Find a value for the variable x that would make $log_2(3x + 2) = 5$ a true statement.

    a) 2
    b) 4
    c) 6
    d) 8
    e) 10

22. Determine the focus of the equation $x^2 = 20y$

    a) (0,20)
    b) (0,4)
    c) (0,5)
    d) (4,0)
    e) (5,0)

23. Which of the equations graphs the following ellipse? (each gridline is one unit)
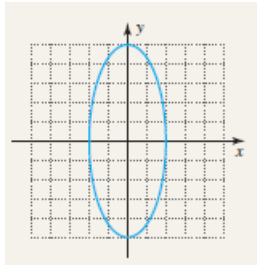
    a) $\dfrac{x^2}{4} + \dfrac{y^2}{25} = 1$

    b) $\dfrac{x^2}{8} + \dfrac{y^2}{5} = 1$

    c) $\dfrac{x^2}{2} + \dfrac{y^2}{25} = 1$

    d) $\dfrac{x^2}{4} + \dfrac{y^2}{5} = 1$

    e) $\dfrac{x^2}{25} + \dfrac{y^2}{2} = 1$

Use the equation $y = \frac{2x-6}{3x+9}$ to answer questions 24-27.

24. What is the x-intercept of the equation?

   a) (2,0)
   b) (3,0)
   c) (4,0)
   d) (1,0)
   e) (0,0)

25. Identify the vertical asymptote(s).

   a) $x = -3 \; and \; x = 3$
   b) $x = -3$
   c) $x = 3$
   d) $x = \frac{3}{2}$
   e) $x = 0$

26. Identify the horizontal asymptote.

   a) $y = 0$
   b) $y = \frac{2}{3}$
   c) $y = 3$
   d) $y = 2$
   e) no solution

27. What is the y-intercept of the equation?

   a) (0,0)
   b) $(0, \frac{1}{3})$
   c) $(0, -\frac{1}{3})$
   d) $(0, -\frac{2}{3})$
   e) (0,3)

28. A total of 800 tickets were sold for the musical *A Comedy of Errors*, adult tickets cost $12 and student tickets cost $5. A total of $7100 was collected from ticket sales. Which of the following system of equations would be used to find out how many of each type of ticket where sold?

a) $\begin{cases} 5x + 12y = 800 \\ 5x + 12y = 8000 \end{cases}$

b) $\begin{cases} x + 12y = 7100 \\ x + 5y = 800 \end{cases}$

c) $\begin{cases} 5x + 12y = .055 \\ x + y = 8000 \end{cases}$

d) $\begin{cases} 5x + 12y = 7100 \\ x + y = 800 \end{cases}$

e) $\begin{cases} 5x + 12y = 800 \\ 5x + 12y = 7100 \end{cases}$

29. Which of the following matrices would be used to solve the system of equations?
$$\begin{cases} 3x + 4y = 7 \\ x = y + 2 \end{cases}$$

a) $\begin{bmatrix} 3 & 4 & 7 \\ 1 & -1 & 2 \end{bmatrix}$

b) $\begin{bmatrix} 3 & 4 & 7 \\ 1 & -1 & 0 \end{bmatrix}$

c) $\begin{bmatrix} 4 & 4 & 7 \\ 1 & -1 & 0 \end{bmatrix}$

d) $\begin{bmatrix} 3 & 4 & 7 \\ 1 & -1 & -2 \end{bmatrix}$

e) $\begin{bmatrix} 3 & 4 & 7 \\ 1 & 1 & 0 \end{bmatrix}$

30. The expression $\frac{3x+13}{x^2+5x+6}$ decomposes into partial fractions of the form $\frac{A}{x+2} + \frac{B}{x+3}$. Find the value of A.

a) 4
b) 5
c) 6
d) 7
e) 8

College Algebra Readiness Exam [ ]   Name:_____

Instructions: Write your solution for each problem in the space provided. Calculators are not to be used on this exam.

1) Solve $x + 3 = 7$ for x.   _____

2) If $x = 3$ and $y = 4(x + 2)^2 + 7$, find y.   _____

3) Evaluate $\frac{0}{8}$ and $\frac{8}{0}$.   ____ and ____

4) Simplify (i.e. remove parentheses and combine like terms)   _____
$x(3x + 7) + (2x + 1)$.

5) Factor $5x^2 - 2x$.   _____

Please continue on the reverse.

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6) True or false: $(x+3)^2 = x^2 + 9$. _____

7) Factor $x^2 - 4$. _____

8) Evaluate $\frac{4}{5} + \frac{2}{3}$. _____

9) Simplify $\sqrt[3]{8}$. _____

10) Use the graph to estimate the value of $f(2.5)$. _____
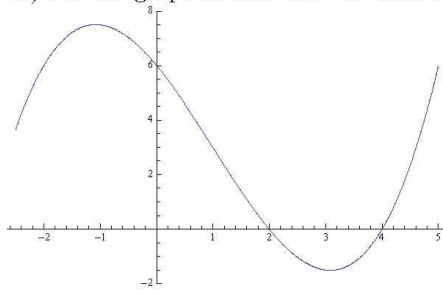
Course Textbook Information

The textbook for the course is Coburn's College Algebra 2nd Edition (2010). The introduction

acknowledges that college algebra tends to be a challenging course for many students. Coburn

states:

> "Our students come to us with a wide range of backgrounds, varying degrees of
> preparations and interest levels that vary from apathy to excitement. In addition, our
> classes include those needing only a general education requirement, as well as our
> country's future engineers and scientists. To say our greatest challenge is meeting the
> needs of so diverse a population would be an understatement." (Coburn, 2010, p. vii)

Units and sections from Coburn covered and assessed in college algebra

Chapter 1 – Equations and Inequalities

- o 1.1 Linear Equations, Formulas, and Problem Solving

- o 1.2 Linear Inequalities in One Variable

- o 1.4 Complex Numbers

- o 1.5 Solving Quadratic Equations

- o 1.6 Solving Other Types of Equations

Chapter 2 – Relations, Functions and Graphs

- o 2.1 Rectangular Coordinates; Graphing Circles and Other Relations

- o 2.2 Graphs of Linear Equations

- o 2.3 Linear Graphs and Rates of Change

- o 2.4 Functions, Function Notation, and the Graph of a Function

- o 2.5 Analyzing the Graph of a Function

- o 2.6 The Toolbox Functions and Transformations

- o 2.7 Piecewise-Defined Functions

Chapter 3 – Polynomial and Rational Functions

- o 3.1 Quadratic Functions and Applications

- o 3.2 Synthetic Division; The Remainder and Factor Theorems

- o 3.3 The Zeroes of Polynomial Functions

- o 3.4 Graphing Polynomial Functions

- o 3.5 Graphing Rational Functions

- o 3.7 Polynomial and Rational Inequalities

- o 3.8 Variation: Function Models in Action

Chapter 4 – Exponential and Logarithmic Functions

- o 4.1 One-to-One and Inverse Functions

- o 4.2 Exponential Functions

- o 4.3 Logarithms and Logarithmic Functions

- o 4.4 Properties of Logarithms; Solving Exponential Logarithmic

- o 4.5 Applications from Business, Finance, and Science

Additional Topics

- o 5.1 Linear Systems in Two Variables with Applications

- o 5.2 Linear Systems in Three Variables with Applications

- o 6.1 Solving Systems Using Matrices and Row Operations

- o 6.4 Applications of Matrices and Determinants: Partial Fractions

- o 7.2 The Circle and the Ellipse

- o 7.4 The Analytic Parabola

- o 8.1 Sequences and Series

Table B.1

Item and Reliability Item-Total Statistics for Common Final Exam

	Item Mean	Item Std. Deviation	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Q1	.92	.276	19.80	24.962	.398	.806
Q2	.78	.412	19.93	24.838	.275	.808
Q3	.69	.463	20.02	24.063	.410	.803
Q4	.74	.439	19.97	24.639	.300	.808
Q5	.58	.495	20.14	23.631	.470	.800
Q6	.50	.501	20.22	24.138	.355	.805
Q7	.78	.412	19.93	24.592	.337	.806
Q8	.77	.421	19.94	24.427	.369	.805
Q9	.82	.384	19.89	24.895	.286	.808
Q10	.55	.499	20.17	23.706	.450	.801
Q11	.93	.255	19.78	25.270	.313	.808
Q12	.77	.423	19.95	24.690	.302	.807
Q13	.85	.360	19.87	25.042	.268	.809
Q14	.79	.407	19.92	24.504	.364	.805
Q15	.37	.482	20.35	24.088	.384	.804
Q16	.84	.370	19.88	25.202	.215	.810
Q17	.84	.367	19.87	25.264	.201	.811
Q18	.41	.492	20.31	23.920	.410	.803
Q19	.76	.429	19.96	24.588	.321	.807
Q20	.56	.497	20.15	24.821	.216	.811
Q21	.58	.495	20.14	23.818	.430	.802
Q22	.47	.500	20.25	24.473	.286	.808
Q23	.79	.407	19.92	24.817	.284	.808
Q24	.82	.382	19.89	25.398	.155	.812
Q25	.56	.497	20.15	23.970	.395	.804
Q26	.56	.497	20.15	24.641	.254	.810
Q27	.70	.459	20.01	24.133	.398	.804
Q28	.86	.351	19.86	25.296	.204	.811
Q29	.80	.398	19.91	25.002	.246	.809
Q30	.33	.469	20.39	24.658	.270	.809

Note: *N*=301 for all items

Table B.2

Common Final Exam Descriptive Statistics for Top and Bottom 27%

	n	Top 27% Mean	Top 27% Std. Deviation	Bottom 27% Mean	Bottom 27% Std. Deviation
Q1	81	1.00	.000	.74	.441
Q2	81	.89	.316	.54	.501
Q3	81	.90	.300	.37	.486
Q4	81	.93	.264	.56	.500
Q5	81	.91	.283	.25	.434
Q6	81	.77	.426	.22	.418
Q7	81	1.00	.000	.53	.502
Q8	81	.96	.190	.52	.503
Q9	81	.98	.156	.67	.474
Q10	81	.93	.264	.25	.434
Q11	81	1.00	.000	.79	.410
Q12	81	.95	.218	.56	.500
Q13	81	.98	.156	.73	.448
Q14	81	.96	.190	.53	.502
Q15	81	.68	.470	.14	.345
Q16	81	.96	.190	.70	.459
Q17	81	.93	.264	.70	.459
Q18	81	.75	.434	.11	.316
Q19	81	.93	.264	.53	.502
Q20	81	.79	.410	.41	.494
Q21	81	.84	.369	.22	.418
Q22	81	.72	.454	.23	.426
Q23	81	.95	.218	.58	.497
Q24	81	.94	.242	.73	.448
Q25	81	.85	.357	.27	.448
Q26	81	.79	.410	.37	.486
Q27	81	.94	.242	.38	.489
Q28	81	.95	.218	.75	.434
Q29	81	.96	.190	.60	.492
Q30	81	.63	.486	.20	.401

Table B.3

Reliability Item-Total Statistics Algebra Readiness Pretest – All Items

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Q1	4.06	5.149	.038	.680
Q2	4.51	4.604	.168	.681
Q3	4.82	4.438	.365	.641
Q4	4.39	4.288	.346	.643
Q5	4.64	4.117	.438	.624
Q6	4.61	4.288	.335	.646
Q7	4.56	4.049	.457	.619
Q8	4.31	4.321	.365	.640
Q9	4.55	3.972	.498	.610
Q10	4.73	4.564	.229	.666

Table B.4

Reliability Item-Total Statistics Algebra Readiness Pretest – Items 1 & 2 Deleted

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Q3	3.35	3.845	.356	.674
Q4	2.92	3.661	.363	.672
Q5	3.17	3.505	.455	.651
Q6	3.13	3.692	.333	.680
Q7	3.09	3.430	.480	.644
Q8	2.83	3.707	.374	.670
Q9	3.08	3.393	.502	.639
Q10	3.26	3.951	.227	.701

Table B.5

Reliability Item-Total Statistics for Algebra Readiness Posttest - All Items

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Q1	5.43	5.059	.145	.689
Q2	5.77	4.225	.370	.658
Q3	6.08	4.258	.367	.659
Q4	5.61	4.356	.396	.655
Q5	5.86	4.101	.417	.648
Q6	5.68	4.379	.329	.666
Q7	5.75	4.158	.414	.649
Q8	5.66	4.413	.323	.667
Q9	5.79	4.190	.385	.655
Q10	6.02	4.392	.275	.677

Table B.6

Reliability Item-Total Statistics for Algebra Readiness Posttest – Item 1 Deleted

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
Q2	4.80	4.119	.360	.664
Q3	5.10	4.135	.367	.662
Q4	4.64	4.238	.392	.659
Q5	4.89	3.976	.419	.651
Q6	4.71	4.250	.331	.669
Q7	4.78	4.032	.416	.652
Q8	4.69	4.286	.324	.671
Q9	4.81	4.062	.388	.658
Q10	5.04	4.272	.272	.682

Table B.7

Descriptive Statistics Algebra Readiness Pretest Top 27th Percentile

	N	Mean	Std. Deviation
Q2	56	.82	.386
Q3	56	.55	.502
Q4	56	.93	.260
Q5	56	.86	.353
Q6	56	.88	.334
Q7	56	.93	.260
Q8	56	.98	.134
Q9	56	.95	.227
Q10	56	.57	.499
Valid N (listwise)	56		

Table B.8

Descriptive Statistics Algebra Readiness Pretest Bottom 27th Percentile

	N	Mean	Std. Deviation
Q2	56	.29	.456
Q3	56	.04	.187
Q4	56	.23	.426
Q5	56	.04	.187
Q6	56	.16	.371
Q7	56	.07	.260
Q8	56	.29	.456
Q9	56	.02	.134
Q10	56	.11	.312
Valid N (listwise)	56		

Table B.9

Descriptive Statistics Algebra Readiness Posttest Top 27th Percentile

	N	Mean	Std. Deviation
Q2	56	.96	.187
Q3	56	.84	.371
Q4	56	.98	.134
Q5	56	.95	.227
Q6	56	.95	.227
Q7	56	.95	.227
Q8	56	1.00	.000
Q9	56	.98	.134
Q10	56	.77	.426
Valid N (listwise)	56		

Table B.10

Descriptive Statistics Algebra Readiness Posttest Bottom 27th Percentile

	N	Mean	Std. Deviation
Q2	56	.25	.437
Q3	56	.02	.134
Q4	56	.36	.483
Q5	56	.13	.334
Q6	55	.33	.474
Q7	56	.18	.386
Q8	56	.41	.496
Q9	56	.16	.371
Q10	56	.07	.260
Valid N (listwise)	55		