DISSERTATION

THE ROLE OF FREQUENCY AND CROSS-ABILITY PEER TUTORING ON STUDENT PERFORMANCE IN A COLLEGIATE, DEVELOPMENTAL MATHEMATICS CLASSROOM

Submitted by

Nadine Filosi Dame

School of Education

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Doctoral Committee:

Advisor: Gene W. Gloeckner
Co-Advisor: Paul A. Kennedy

Karen Kaminski
Kelly Chappell

ABSTRACT

THE ROLE OF FREQUENCY AND CROSS-ABILITY PEER TUTORING ON STUDENT PERFORMANCE IN A COLLEGIATE, DEVELOPMENTAL MATHEMATICS CLASSROOM

This study examines the differences between spacing of instruction and the classroom involvement of a cross-ability peer tutor on mathematical achievement in a developmental mathematics course. Grounded in spacing effect theory, this study examines how variations in the frequency of instruction affect student learning. The study consists of two segments conducted sequentially, specifically a quantitative analysis that was further supported by a qualitative inquiry. Results of the strong quasi-experimental study show that the mathematical achievement of students whose class met once per week for two hours was significantly lower than those students whose class met for one hour, twice per week. Through the use of student panel interviews, an interview with the cross-ability peer tutor and another with the faculty member, the qualitative findings suggest that many students may prefer the convenience of condensed class schedules that minimize their time spent on campus. For students enrolled in a developmental mathematics program at the collegiate level, these condensed scheduling options, however, may sacrifice learning for convenience.

DEDICATION

To my parents, Lou and Con, for your unwavering support. You have always been committed to my future, and have spent my lifetime preparing me for this journey.

To my husband, Dave, for supporting our household while I banished myself to the office. You have been compassionate, reassuring, patient, and always loving. I would be nothing without you.

Finally, to my wonderful children, Russell and Allison who, without even knowing it, helped me keep everything in perspective. I owe everything to you, because you are why I have chosen this path. I dedicate this to your future.

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CHAPTER ONE: INTRODUCTION

> Mathematics is the key to opportunity. No longer just the language of science, mathematics now contributes in direct and fundamental ways to business, finance, health, and defense. For students, it opens doors to careers. For citizens, it enables informed decisions. For nations, it provides knowledge to compete in a technological economy (National Research Council, 1989, p. 1).

This observation, made more than two decades ago, still reverberates today, supported by three key motives. First, mathematics has become increasingly important and even central to many fields that were not so mathematically dependent. Second, an increasing number of students are entering postsecondary institutions with limited mathematical abilities. Third, full-time employment is directly related to one's highest level of degree attainment and mathematics classes are often indicative of student success.

Mathematics has become increasingly important and even central in many fields that traditionally were not so mathematically dependent. More recently, similar sentiments have been expressed by the National Mathematics Advisory Panel (2008), and the American Mathematical Association of Two-Year Colleges (AMATYC), (2006). The AMATYC report states "Employees are now expected to be quantitatively literate and possess a high level of specific mathematical skills" (p. 76). Independently, this increased reliance on the study of mathematics is not problematic.

Coupling an increased reliance of mathematics along with an escalating college enrollment of underprepared students puts added pressure on an already strained labor force. The National Center for Education Statistics reports that enrollment in postsecondary degree granting institutions has increased 38% between 1999 and 2009 and 51% between 1989 and 2009, from 13.5 million to 20.4 million students. Much of the growth between 1999 and 2009 was in full-time enrollment; the number of full-time students rose 45%, while the number of part-time students rose 28% (National Center for Education Statistics, 2010). Reasons for this increase may include higher paying salaries and increased likelihood of fulltime employment.

Perhaps the drive for higher paying salaries and full time employment encourages students to further their education. According to the National Center for Educational Statistics (2010), the 2008 mean annual income of someone who has not earned a high school diploma is $23,500, but $30,000 for someone whose highest degree attained is a high school diploma. Compare that to an income $50,000 for someone who has earned a bachelor's degree and there is little doubt that income potential may be a motivating factor (National Center for Education Statistics, 2010).

Perhaps also contributing to the increased demand of higher education is the increase of fulltime employment availability. In 2008, the percentage of young adults ages 25-34 in the labor force working full-time, full-year was generally higher for those with higher levels of educational attainment. For example, 72% of young adults with a minimum of a bachelor's degree were full-time, full-year workers in 2008, compared with only 62% of young adults with a high school diploma or its equivalent (National Center for Education Statistics, 2010).

Compounding the difficulties posed by this increase in enrollment is a higher percentage of students who are quantitatively illiterate and a greater reliance on mathematics across many disciplines not traditionally so. The Organization for Economic Cooperation and Development, defines quantitative literacy as "the capacity to identify, understand and engage in mathematics as well as make well-founded mathematical judgments about the role that mathematics plays in individual's current and future life as a constructive, concerned and reflective citizen" (American Mathematical Association of Two Year Colleges, 2006, p. 10).

Continually evolving are the mathematical skills and knowledge required for one's successful professional and personal life. "To be productive, citizens need to be quantitatively literate….To make informed decisions and understand issues, citizens must be able to analyze data, reason with statistics, and understand mathematical models" (American Mathematical Association of Two Year Colleges, 2006, pp. 37-38). Previously non-technical disciplines have succumbed to the many advances of mathematics and science. "The world has gone quantitative: business, geography, criminal justice, history, allied health fields—a full range of disciplines and job tasks tells students why math requirements are not just some abstract school exercise" (Adelman, The Toolbox Revisited: Paths to Degree Completion from High School through College, 2006, p. xix).

Enrolled students who are not yet prepared for college-level mathematics are challenging educators nationwide. From 2006 through 2009, the ACT College Readiness benchmark score for mathematics has remained relatively constant, fluctuating between 42% and 43%. This indicates that less than 43% of all graduating high school seniors in the United States have a 50% chance of obtaining a B or higher, or a 75% chance of obtaining a C or higher in the corresponding credit-bearing college courses (ACT, 2010). The failure is not due to global disinterest; interest in student achievement has remained high amidst many changes in the social, political and technological advances of recent years. Despite this interest, mathematical achievement in the general student population remains at an unacceptable level.

The purpose is neither to place blame nor change policy at the primary or secondary levels; it is merely to suggest that there is validity behind the hypothesis that developmental education is currently a necessary aspect of higher education as it exists today. The combination of underprepared college students as well as an ever changing student population highlights the need for continued research on best methodologies for teaching effectiveness.

Research Problem

Students who place into developmental mathematics classes at the postsecondary level enter college without the necessary understanding of the fundamental principles of mathematics including arithmetic, simplifying expressions, solving linear algebra equations, and problem solving. Until corrected, this deficiency disables them from succeeding in a college level mathematics class. The literature exposes a lack of research on the effects of frequency of instruction and cross-ability peer tutors on the mathematical achievement of students enrolled in developmental mathematics classes at the collegiate level. This void reveals the research problem, the need for more data on the value of frequency of instruction and cross-ability peer tutors in a collegiate, developmental mathematics program.

Statement of Purpose

The purpose of this sequential explanatory mixed method design, as shown in Figure 1, is to examine the possible differences between frequency of instruction, a cross-ability peer tutor, and gender on mathematical achievement of students enrolled in a developmental mathematics class at a private, not for profit, degree granting university. The embedded qualitative data will serve a supportive role (Creswell & Plano-Clark, 2007) to the quantitative data. In addition to adding to the body of literature, this study may serve to both inform faculty about sound pedagogical methods and be utilized by administration to prepare an instructional framework for more effective learning in the collegiate developmental mathematics classroom.

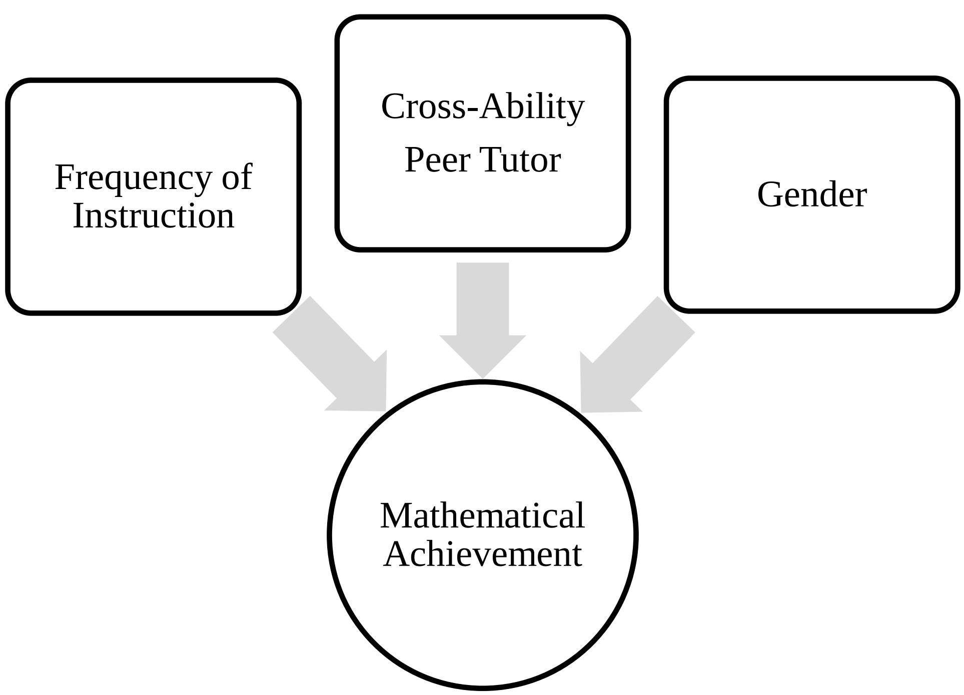

Figure 1. Conceptual framework for the proposed research.

Independent variables “include any predictors, antecedents, or presumed causes or influences under investigation in the study” (Morgan, Gliner, & Harmon, 2006, p. 33). These independent variables include frequency of instruction, cross-ability peer tutoring, and gender. Frequency of instruction represents how often the class is scheduled to meet, without modification to the total length of instructional time. This independent variable has two levels, meeting two hours once per week or one hour twice per week. In cross-ability tutoring, “ the student acting as tutor has already attained greater mastery of the subject or material being taught, while the other student might be struggling” (Allen, 2011). Whether the cross-ability tutor is assigned to assist the faculty member in the classroom, or not, also designates this independent variable as dichotomous. The four instructional methods, each with two levels, are depicted in Table 1.

Table 1
Summary of Instructional Methods

	Frequency of Instruction	
Tutor Assistance	Once Per Week	Twice Per week
Cross-Ability Tutor	Once per week, with tutor	Twice per week, with tutor
No Cross-Ability Tutor	Once per week, no tutor	Twice per week, no tutor

Research Questions

The following research questions were developed with the intent of examining the possible differences between frequency of instruction, a cross-ability peer tutor, and gender on mathematical achievement of students enrolled in a developmental mathematics class at a private, not for profit, degree granting university

1. Is there a difference between pretest and posttest scores for students enrolled in a developmental mathematics course at a private, not for profit, university?
2. For students in a developmental mathematics course at a private, not for profit, university, is there a difference in mathematical achievement between students who meet once a week for two hours, or twice a week for one hour each?
3. For students in a developmental mathematics course at a private, not for profit, university, is there a difference in mathematical achievement between students whose class had a cross-ability peer tutor available during class and those who did not?
4. For students in a developmental mathematics course at a private, not for profit, university, is there a difference in mathematical achievement between students of different genders?
5. For students in a developmental mathematics course at a private, not for profit, university, is there a significant interaction effect between frequency of instruction and gender on mathematical achievement?
6. For students in a developmental mathematics course at a private, not for profit, university, is there a significant interaction effect between frequency and tutor participation on mathematical achievement?

7. For students in a developmental mathematics course at a private, not for profit, university, is there a significant interaction effect between gender and tutor participation on mathematical achievement?
8. For students in a developmental mathematics course at a private, not for profit, university, are there any significant three or four way interactions between gender, frequency of instruction, tutor participation, and mathematical achievement?
9. What underlying perceptions do students recognize with regard to the frequency of instruction?
10. What underlying perceptions do students recognize with regard to the participation of a cross-ability peer tutor during classroom instruction?

Definitions of Terms

Developmental Mathematics: A *Developmental Mathematics* program includes precollege level mathematics courses established by colleges to prepare students for college level coursework. Synonymous terminology may include remedial or precollege mathematics.

Cross-Ability Tutoring: *Cross-Ability Tutoring* is a peer tutoring approach in which “the student acting as the tutor has already attained greater mastery of the subject or material being taught” (Allen, 2011).

Cross-Age Tutoring: *Cross-Age Tutoring* is a peer tutoring approach that joins students of different ages, with older students assuming the role of tutor and younger students assuming the role of tutee (Scott-Little & Valentine, 2004).

Mathematical Achievement: *Mathematical Achievement* refers to a variable created by the statistics program, SPSS, which is a combination of the two repeated measures, a pretest and posttest.

Peer Tutoring: *Peer tutoring* is an instructional strategy "characterized by specific role taking: at any point someone has the role of tutor whereas the other (or the others) is in role of tutee" (Topping & Ehly, 1998). Variations of peer tutoring strategies include cross-ability tutoring, reciprocal peer tutoring, and other peer assisted learning strategies.

Tutor Training Program: The *Tutor Training* program includes a discussion of goals, behavior and academic problem solving strategies, and appropriate feedback and reinforcement strategies (Miller, Barbetta, & Herron, 1994).

Limitations and Delimitations

When designing research, it is important to identify both the possible limitations and purposeful delimitations of the study. By identifying limitations, the researcher may be able alter the design in order to minimize the current study's limitations. Secondly, recognizing the study's limitations lessens the likelihood that the researcher will inaccurately report or generalize results from the study. Furthering, or repeating, the current research is facilitated by clearly defined limitations.

For this proposed study, delimitations focus on the selected sample. The study will examine developmental mathematics classes at a, private, nonprofit, degree granting university located in an urban city of the Western United States. The annual enrollment hover around 1,500 students with about 40% of the incoming class placing into a developmental mathematics class. This study focuses on developmental mathematics students enrolled at one university thus minimizing its external validity. Potential results may be unique to the one university; caution should be exercised when generalizing this study.

Limitations also focus on the sample. The researcher is neither in control of student nor faculty scheduling. One faculty member has been asked to teach the vast majority of classes, however, not all offered classes can be taught by one person. The faculty member teaching all the developmental classes for this study is not involved with the research project. This is beneficial with regard to minimizing biases, but the lack of control over the data increases the chance for error. Similarly, one cross-ability peer tutor has been assigned to this study, his own academic and work schedule will dictate which classes he is available to act as the cross-ability peer tutor. Although the faculty member is not part of the research team, he is aware of the study and implications of the instructional methods. To minimize instructor bias, consistency across the mathematics curriculum is followed, regardless of the teaching methodology in the classroom. All students, regardless of condition, are therefore assessed with the same instruments.

Researcher's Perspective

Another potential limitation of this study, which can never be ignored with any study, is researcher bias. As the study progresses, all attempts will be made to minimize such biases. As both a researcher and mathematics faculty member, my interest in this topic is far reaching. With more than ten years of teaching experience at this university, and an additional five years of teaching experience prior, I bring to this study my own understanding and experiences of teaching students. Along with that teaching experience, I bring my own personal thoughts and feelings about developmental mathematics education. Conversations with colleagues at the university about how to teach to this group of students have also exposed me to their biases surrounding their experiences and opinions toward remedial mathematics education. In preparation for this study, we are mindful of these biases and will attempt to minimize their impact.

As a faculty member, it is my responsibility to determine the best methods to instruct students. Devising a best teaching strategy is often compounded by several factors including faculty resources, student availability, and university resources. Utilizing cross-ability peer tutors in the classroom has the potential to maximize student performance in the developmental mathematics classroom. It is our experience that student employees are underutilized and faculty are overwhelmed. Developing qualified student employees as cross-ability tutors may further engage student employees while simultaneously reducing the workload of faculty.

Significance of the Study

Providing students, enrolled in developmental mathematics courses, with a greater chance for success is the primary aim of this study. The means to this end, however, are numerous and many are indirect. Directly, the results of this study will be explored by the university where the study was conducted. Further, this study has the potential to contribute to the greater academic research community by filling a small void in the literature on the effects of frequency of instruction and cross-ability peer tutoring on mathematical achievement in the developmental mathematics classroom. Developing qualified student employees as cross-ability tutors may further engage student employees while simultaneously reducing the workload of faculty. Indirectly, this study may aid students by acquainting them with peer tutors and engaging students who otherwise may have been disconnected to a school's resources.

Potential for Publication

The void in the literature on this topic, along with anecdotal experience at mathematical conferences at both the regional and national level leads one to believe that the results of this study may be useful to a variety of people in academia. The results of the proposed study certainly have the potential for publication and a segment of the academic population should find these results useful. University administration may use the results of this study to support academic scheduling initiatives and more effective use of cross-ability peer tutors. Similarly, individual faculty members may find the results useful for classroom preparation and scheduling of material. Lastly, this study may add one more facet to the existing body of developmental mathematical education literature.

CHAPTER 2: LITERATURE REVIEW

Research of mathematics education in the United States is not lacking; discussions, opinions, and studies on this topic have been documented for well over a century. Although a national curriculum is yet to exist, the United States is well on its way to creating nationally accepted standards for what and how mathematics should be taught in the primary and secondary grade levels.

This literature review begins with a historical prospective of teaching methodologies and content standards for primary and secondary school children over the past century. A more narrowed timeline of their student achievement follows with regard to standardized testing over the past 20 years. As will be revealed, many students are accepted to post-secondary institutions without the mathematical skills necessary to be successful studying collegiate level mathematics. The focus of the literature review narrows with an investigation of developmental mathematics education at the post-secondary level. Further scrutiny of existing studies will be conducted pertaining to selected internal and external influences and their effects on academic achievement. These variables include gender, self-efficacy, and supplemental instruction with an emphasis on those studies which reference mathematics education at the post-secondary level.

Teaching Methodology and Content Requirements for Primary and Secondary Mathematics Education in the United States since the Turn of the 20th Century

The best method to educate our nation's school children has been debated for well over a century with the primary struggle rooted in the conflict between content requirements and teaching methodologies. David Klein (2003) reasons, if decisions are based strictly on learning content objectives then the choices of teaching methodologies become limited. Klein maintains that content learning precludes student centered, discovery learning because that particular teaching methodology requires more time than content requirements allow. Conversely, if decisions are based strictly on teaching style and student centered discovery learning drives the curriculum, then measuring content objectives becomes an immeasurable task. Therein lies the paradox.

Turn of the 20th Century

Due to a lack of consensus about education issues, the National Education Association created the first national committee, the Committee of Ten, during the turn of the 20th century (Ravitch, 2000). Asked to study educational issues and offer constructive proposals for students in the United States, the Committee of Ten promptly responded to the request by the National Education Association. The 1893 report cited that all students, not just those bound for college, should study a wide field of academics, including mathematics, science, history, literature, language and the arts (Ravitch). This marked the beginning of national debates regarding education reform. Opposition arose quickly in support of a differentiated curriculum which offers career based education for the majority of students and an academic curriculum for a small minority (Ravitch).

During the early part of the 20th century, the government again recognized the need to reorganize the primary and secondary educational system in the United States. The United States Bureau of Education's Commission on the Reorganization of Secondary Education asked William Heard Kilpatrick to chair a committee to study mathematics in the high schools. Often overshadowed by John Dewey and Harold Rugg as an important influence of the progressive movement during the 20th century, E. D. Hirsch credits Kilpatrick with being "the most influential introducer of progressive ideas into American schools of education" (The Schools We Need And Why We Don't Have Them, 1996, p. 52). Kilpatrick understood the larger problem of education in the United States as stated in the preface of his 1920 report which reads "Antecedent to new courses, there should be an agreement among psychologists and educators such as has not yet been reached" (Kilpatrick, 1920, p. 8). Kilpatrick's report contained a consistent progressive message that schools needed to be more child-centered, democratic, and socially oriented (Klein, 2003). The committee, comprised entirely of educators and school administrators, directly challenged the 1893 report that touted benefits of teaching mathematics to the majority of school children. In the report, Kilpatrick recommended "No item shall be retained for any specific group of pupils unless, in relation to other items and to time involved, its (probable) value can be shown" (Kilpatrick, 1920, p. 15), and recommended the traditional high school mathematics curriculum for only a select few. Opposition began to mount even before Kilpatrick's report was published (Klein).

The two most formidable opponents of Kilpatrick's report were the Mathematical Association of America (MAA) and the National Council of Teachers of Mathematics (NCTM). In 1916, the Mathematical Association of America formed the National

Committee on Mathematical Requirements. Unlike Kilpatrick's committee, this committee was comprised of teachers and administrators as well as mathematicians (Klein, 2003). The committee composed a number of reports which were compiled into a volume entitled *The Reorganization of Mathematics for Secondary Education* and was published in 1923; it is often called the *1923 Report.* The National Council of Teachers of Mathematics (NCTM) was founded in 1920 and later played an important role in disseminating the *1923 Report* (Ravitch, 2000). In contradiction to the Kilpatrick report, the *1923 Report* underscored the importance of Algebra to "every educated person" (Osborne & Crosswhite, 1970, p. 203).

Mid-Century

In the 1940s, the United States Army realized that their recruits knew so little about mathematics that the Army itself had to provide training in basic arithmetic needed for bookkeeping and gunnery (Raimi, 2000). After World War II, critics attacked many of the ideas and practices of progressive education; student centered, discovery learning was still widely supported at that time. Critics saw a curriculum that lacked rigor and students who were academically unprepared to compete with in a global economy (Raimi). Progressive education was therefore forced into retreat in the 1950s and New Math emerged.

Clearly a move away from the anti-intellectualism of the previous half-century of progressivist doctrine, New Math emphasized coherent logical explanations for the mathematical procedures taught in the schools. And, for the first time, mathematicians were actively involved in contributing to primary and secondary mathematics curricula (Klein, 2000). Public attention toward mathematics education was limited until the fall of 1957 when the U.S.S.R. launched *Sputnik*, the first space satellite, into orbit. Humiliated by not being the first country to put a satellite into orbit, Americans once again called attention to the low quality of mathematics instruction in the public schools. "The Russian success alerted the American public to deficiencies in their school system, to the need for providing their young people with an educational base wide enough to permit them to cope with the multiplying problems of swift technological change" (NASA, 2003). Congress quickly responded and passed the 1958 National Defense Education Act which aimed at increasing the number of mathematics, science, and foreign language majors (Aud, et al., 2010).

New Math continued with little opposition until the mid-1970s when there was a call to go back to basics. Progressive education, however, had also regained momentum. (Klein, 2003). As in earlier periods of the 20th century, the agenda of progressivist educators was resisted by broad sectors of the public, and the chasm between those who favored student and teacher directed learning still existed. Two reports soon surfaced reflecting their opposing viewpoints; *An Agenda for Action* published by NCTM in 1980 and the governmental report, *A Nation at Risk* published in 1983. The differing perspectives and prescriptions for change characterize the opposing factions of educational methodologies. Often overshadowed, *An Agenda for Action* called for new directions in mathematics education and recommended that problem solving be the focus of school mathematics along with new ways of teaching. Additionally, it called for "a wider range of measures than conventional testing" (National Council of Teachers of Mathematics, 1980).

The more widely recognized document of the 1980s, *A Nation at Risk,* captured the attention of the public, educators, administrations, and policy-makers nationwide. *A Nation at Risk* warned, "Our nation is at risk...the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a Nation and a people" (National Commission on Excellence in Education, 1983, p. 9). This report addresses a wide variety of educational issues, including direct reference to remedial mathematics, "Between 1975 and 1980, remedial mathematics courses in public 4-year colleges increased by 72 percent and now constitute one-quarter of all mathematics courses taught in those institutions" (National Commission on Excellence in Education, 1983, p. 11).

Reacting to these reports and widespread public concern, states and school districts attempted to make changes at the local level. Numerous states began to collect statistics to measure their own programs and many teachers began to implement student centered pedagogies in their classrooms. These innovations included cooperative learning, team teaching, individualization of instruction, and experiential education.

With public opinion in support of a strong focus on basic skills and clear high standards, the NCTM created the *Curriculum and Evaluation Standards for School Mathematics*. The final document, published in 1989, did not include standards in the usual sense of the word. Rather, very broad based goals which students were to accomplish in each four-year cluster of grades: K-4, 5-8, and 9-12 frame the standards. Although the central theme of the *NCTM Standards* echoed those from the *Agenda for Action* and progressive education dating back to the 1920s, advocating student centered, discovery learning, it was received with much more praise. Immediately endorsed by the

National Science Foundation, American Mathematical Society, the Mathematical Association of America, and many others, the *NCTM Standards* became a point of reference for primary and secondary grade mathematics and by 1997, most state governments had adopted or revised their mathematics standards to be in close alignment with the NCTM Standards (Raimi, 2000).

The National Science Foundation (NSF) was a strong supporter of the *NCTM Standards*, in particular constructivist teaching methodologies, and supported many creations and distributions of mathematics books and programs aligned to those standards. Following the NSF lead, many districts adopted texts which focused on these constructivist teaching methodologies. The public, however, wasn't as enthusiastic about the NCTM mathematics programs, claiming that the mathematical curricula failed to develop fundamental arithmetic and algebra skills. Some parent organizations experienced success in blocking the use of dubious classroom materials and implementing coherent, effective mathematics policies at the state level. A California based parent organization, Mathematically Correct, experienced much success. Its supporters entered the political process, met with reporters and politicians, served on California government panels and commissions related to mathematics education, and testified before national boards and the United States Congress (Klein, 2000). Although it is not possible to teach conceptual understanding without the supporting basic skills, and basic skills are weakened by a lack of understanding, the chasm between those who strictly wanted basic skills taught in the classroom versus those who favored conceptual understanding grew deep.

Turn of the 21st Century through the Present

Educational reform at the turn of the century ended much like it began; splintered. Disagreements between parents, mathematicians, and professional educators continue without clear resolution. In January 1998, the U.S. Education Secretary Richard Riley called for an end to the "math wars" in a speech before a joint meeting of the American Mathematical Society and the Mathematical Association of America. What was important about this was not the message, but that the federal government was stepping in (Loveless, 2002). The turn of the century saw many leading educational groups creating customized content standards which were adopted by only a few. Widespread acceptance of national content standards, unattainable before the turn of the 21st century, may currently be within the grasp of a nation whose educational system has experienced chaos for well over a century.

Beyond content standards, the American Mathematical Association of Two-Year Colleges released its first standards document, *Crossroads in Mathematics*, in 1995. Building on content standards, Crossroads suggested guidelines for selecting content and instructional strategies. The 2006 AMATYC publication, *Beyond Crossroads,* modernized the standards as suggested in Crossroads and introduced Implementation Standards, “which focus on student learning and the learning environment, assessment of student learning, curriculum and program development, instruction, and professionalism” (American Mathematical Association of Two Year Colleges, 2006, p. 1). “To accomplish this alignment, *Beyond Crossroads* has integrated recommendations from AMATYC position statements and related mathematics organizations” (American Mathematical Association of Two Year Colleges, 2006, p. 2) including the NCTM and the

Mathematical Association of America (MAA). In April of 2000, the NCTM released a new document titled, *Principles and Standards for School Mathematics*. This time, they began by commissioning the commentary of many mathematicians, including committees of AMS, MAA, and SIAM as well as advice from the public at large. This revision of the *1989 NCTM Standards* removed some of the more radical declarations and gave a slightly greater emphasis to the importance of arithmetic algorithms and computational fluency. Though, like its predecessor, standards are in its title, it refuses to say what exactly a child should learn in terms of content for a specific grade or course designation.

At the same time the 1989 NCTM Standards was released, the National Governor's Association called for the development of national standards for learning and teaching (Harris, Carr, Flynn, Petit, & Rigney, 1996). Beginning in 2009, a state-led effort organized by the Council of Chief State School Officers (CCSSO) and the National Governors Association Center for Best Practices (NGA Center) began the Common Core State Standards Initiative (CCSSI) (Halka, Heath, & Sandruck, 2010). A short year later, the initiative produced what appears to be one of the most significant and widely accepted changes to the educational landscape in the United States.

The content standards were "developed in collaboration with teachers, school administrators, and experts, to provide a clear and consistent framework to prepare our children for college and the workforce" (National Governors Association Center for Best Practices and Council of Chief State School Officers, 2010). Feedback was solicited from many entities including two direct competitors, the AMATYC and NCTM (Halka, Heath, & Sandruck, 2010), and internationally benchmarked to help ensure students in the United States are globally competitive (Halka, Heath, & Sandruck, 2010). The content standards also address the need for remediation at post-secondary institutions claiming that districts which follow the content standards will produce high school graduates who are "able to succeed in entry-level, credit-bearing academic college courses" (National Governors Association Center for Best Practices and Council of Chief State School Officers, 2010).

Widespread support for the Common Core Standards, initially presented during the spring of 2010, is unmistakable. In the past 18 months, 45 states, the District of Columbia, the U.S. Virgin Islands, and the Northern Mariana Islands have all adopted the Common Core Standards. Even though prior work by NCTM has been overshadowed by these new standards, NCTM remarked that the Common Core Standards are "a welcome milestone in the standards movement" and "we strongly encourage and support both research about the standards themselves and their implementation" (National Council of Teachers of Mathematics (NCTM), the National Council of Supervisors of Mathematics (NCSM), the Association of State Supervisors of Mathematics (ASSM), and the Association of Mathematics Teacher Educators (AMTE), 2010). Still in its infancy it is unclear where the Common Core Standards will take the U.S. educational system but unquestionably, this nation has not seen such widespread support with any other program.

It is unclear whether the paradox between teaching content and using the best pedagogies in primary and secondary mathematics education will continue ad infinitum. Similarly uncertain is whether the Common Core Standards provide "an agreement among psychologists and educators" (Kilpatrick, 1920, p. 8). The history of education in the United States has been anything but consistent; perhaps the most recent Common Core Standards will provide a necessary balance to the U.S. educational system.

Student Achievement at the Primary and Secondary levels

Samples of students across the United States currently participate in up to three national, comparative studies of mathematical knowledge; the Trends in International Mathematics and Science Study (TIMSS), the Program for International Student Assessment (PISA), and the National Assessment of Educational Progress (NAEP). Broadly, these three studies cover similar content; the assessments, however, include differing degrees of relative emphasis, are administered at different times in students' educational progress and to different student populations. Therefore, each has a specific purpose. The TIMSS and NAEP both assess students during the 4th grade, all three assess student knowledge at the 8th grade level, and the NAEP mathematics assessment began to include 12th graders in the spring of 2009.

Trends in International Mathematics and Science Study

The United States Department of Education has been conducting the Trends in International Mathematics and Science Study since 1995. These longitudinal and cross-sectional studies, conducted every 4 years, compare 4th and 8th grade students relative to their peers in other countries, with regard to mathematics and science knowledge and skills. In 2007, 36 countries participated at the 4th grade level and 48 countries participated at the 8th grade level.

The first available results of the third International Mathematics and Science Study (TIMSS), showed 4th graders slightly above the national average in mathematics (United States Department of Education, National Center for Education Statistics, 1997), 8th graders slightly below the international average in mathematics (United States Department of Education, National Center for Educational Statistics, 1996), and 12th

grade students among the lowest of participating nations (United States Department of Education, National Center for Education Statistics, 1998). More recently, however, results of the 2007 TIMSS study showed students in the United States at both the 4^{th} and 8^{th} grade level scored higher than average, scoring greater than almost 64% of 4^{th} graders and 77% of 8^{th} graders (USDOE, 2008).

Results from the 2007 TIMSS show that the United States has a higher percentage of students performing at the higher level. With 10% of 4^{th} grade and 6% of 8^{th} grade students in the United States reaching the advanced benchmark in mathematics, students in the United States outperformed 75% and 79% of its international counterparts, respectively (USDOE, 2008).

Although the norm referenced assessment shows students in the United States improving, relative to their counterparts, the most recent TIMSS criterion based results collected in 2007 show no significant difference in scores between 1995 and 2007 (USDOE, 2008).

Program for International Student Assessment

Similarly, the Program for International Student Assessment measures literacy in reading, mathematics & science of 15 year old students, which is generally comparable to eighth graders in the United States. The PISA, administered by The Organisation for Economic Co-Operation and Development (OECD), is a growing membership of countries whose mission is to “bring together the governments of countries committed to democracy and the market economy” (OECD, 2010). Additionally, the OECD is one of the world’s largest publishers in the fields of economics and public policy. In 2009, 65 countries/economies participated in the assessment, of which 37 were participating OECD members (OECD, 2010).

In comparison to the TIMSS, the 2009 Program for International Student Assessment (PISA) shows the mathematical performance of students from the United States is significantly below average with regard to mathematics. At that time, students from the United States scored 487 points on the mathematical literacy portion of the PISA assessment, significantly lower than the OECD average of 496 (OECD, 2010).

In comparison to the TIMSS, the results of the 2006 PISA show that a higher percentage of students in the United States are performing at a low level, with 10% of its students scoring below 358. On average a score of 379 marked the lowest 10^{th} percentile for OECD jurisdictions. Similarly, data from the 2006 PISA shows that a smaller percentage of students in the United States are performing at high levels. On average, the top 10% of those in OECD jurisdictions scored above 615, whereas the minimum score for the top 10% of students in the United States is 593 (OECD, 2010).

National Assessment of Educational Progress

The National Assessment of Educational Progress is a cross-sectional study administered only to students in the United States during grades 4, 8, and 12, comparable to a student aged 9, 13, and 17, respectively (Jones L. V., 2004). Additionally, The NCES administers the Long-Term Trend assessment to students at specific ages, rather than grade level. The NAEP provides data at both the state and national level; statewide data includes public schools only whereas national assessments include both public and private schools. Although not all are assessed in each grade, eight subject-matter assessments are administered. The arts, civics, economics, geography, and United States history assessments are reported at the national level only, whereas the mathematics, reading, science, and writing assessments are reported at both the state and national levels. The NAEP also provides information on instructional experiences and perceptions of the school environment. More specific sub-groups, such as gender and racial differences, are also measurable with the NAEP.

Results from The National Assessment of Educational Progress, Long-Term Trend Report Card, shows the average scores in mathematics for 9- and 13-year-olds were greater in 2008 than all previous results since 1973. The average score for 9-year olds in 2008 increasing four points since 2004 and 24 points compared to 1973. Thirteen-year-olds scored three points higher than in 2004 and 15 points higher than in 1973. In contrast, the average score for 17-year-olds in 2008 was not significantly different from the scores in 2004 and 1973 (Rampey, Dion, & Donahue, 2009). Significant changes to the 12th grade NAEP in 2005 nullified long term comparison analyses. However, results of the 2009 12th grade NAEP show the average increase of three points over 2005 scores indicate a significant increase, $p<.05$ (National Center for Education Statistics, 2010).

The NAEP mathematics learning gap, represented by the difference between the 10th and 90th percentiles shown in Tables 2, 3, and 4 show that during the past 30 years, the low performing students have seen a greater increase in scores as compared to the high-performing students (National Center for Educational Statistics, 2009).

Table 2
NAEP Mathematics Scores and Learning Gaps for Nine Year Old Students, With Respect to Time and Percentile

	Year		
Percentile	1978	2008	Change
10th	171	198	27
90th	264	284	20
Learning Gap	93	86	-7

Table 3
NAEP Mathematics Scores and Learning Gaps for 13 Year Old Students With Respect to Time and Percentile

	Year		
Percentile	1978	2008	Change
10th	213	237	24
90th	313	323	10
Learning Gap	100	86	-14

Table 4
NAEP Mathematics Scores and Learning Gaps for 17 Year Old Students With Respect to Time and Percentile

	Year		
Percentile	1978	2008	Change
10th	254	267	13
90th	345	343	-2
Learning Gap	91	76	-15

The two international assessments provide unconvincing evidence as to how the average United States student performs compared to their international peers. It is clear, however, that students in the United States still rank far below many other countries in providing a quality education. When comparing low and high-performing students, the results of the two international assessments mirror those results of the average student. These reports specifically target students during primary and secondary education. The ACT and SAT are two national assessment mechanisms which may predict how well students are prepared to succeed in post-secondary education.

ACT and SAT

The ACT testing program is one of two nationally accepted college entrance examinations and includes multiple choice sections whose topics include english, mathematics, reading, and science. The 2010 ACT College Readiness benchmark score for mathematics indicates that only 43% of graduating high school seniors have a 50% chance of obtaining a B or higher or about a 75% chance of obtaining a C or higher in the corresponding credit-bearing college courses (ACT, 2010). The trend from the past five years shows the percent of graduating students who meet the college readiness benchmark in mathematics has fluctuated from 42% to 43% (42,43,43,42,43) (ACT, 2010).

The Scholastic Aptitude Test (SAT) is another nationally recognized standardized college entrance assessment; more than two million students take the SAT annually (The College Board). Results from a 2011 College Board Research Report show that 54% of incoming first year students have a 65 percent probability of obtaining an first year grade point average of a B- or higher in mathematics (Wyatt, Kobrin, Wiley, Camara, & Proestler, 2011). The average SAT scores in mathematics have not increased significantly since 1972, increasing only slightly from 509 to 516 (The College Board, 2010)

It is apparent from both the international and national assessments that the typical United States high school graduate is underprepared to study college level mathematics coursework. Students who wish to study at postsecondary institutions must either take remedial coursework prior to entering or as a first year student. Although mathematical requirements for university studies vary widely depending on the institution and discipline being studied, it is apparent that developmental education is needed at to prepare students to be successful in their postsecondary studies.

Developmental Education at the Postsecondary Level

Remedial education, defined herein as coursework below college level for individual postsecondary institutions, has changed substantially in recent years. Remedial coursework is required for students who enter a postsecondary institution without a certain level of academic proficiency deemed necessary for students to successfully complete their college level coursework. The quantity of remedial classes being offered, to who they are being delivered, and the success of these courses are topics of considerable debate in higher education.

Notably, the quantity of remedial classes that postsecondary institutions offer has drawn considerable attention in recent years. Recent data shows that 76% of all degree-granting 2- and 4-year institutions offered at least one remedial reading, writing, or mathematics course (Parsad & Lewis, 2003). This, however, is a decline from a high of 80% during the 1996 academic year (Snyder & Dillow, 2011). Although many institutions offer remedial education, the number of students enrolling in those classes is significantly less. The 2011 Condition of Education (National Center for Education Statistics, 2011) cites 36% of first year undergraduates, have enrolled in a remedial course, with 20% of first year undergraduates enrolling in more than one. Proportionally, more students enrolled in remedial mathematics courses than in writing, English or reading (15%, 8%, 6%, 6%), respectively. As shown in Table 5, further analysis of the 2011 report (Snyder & Dillow) reveals that the age of remedial students has increased alongside the changing demographics of the average postsecondary student.

Table 5
Percent of Students who Ever Enrolled in a Remedial Course Partitioned by Age and First-Year of Undergraduate Status

	Percent who Ever Enrolled in a Remedial Course	
Age	2003-2004 First-year Undergraduates	2007-2008 First-year Undergraduates
15 to 23	33.6	34.6
24 to 29	34.9	39.5
30 or older	37.4	38.1

While more than 40% of all students enter postsecondary education require remediation, fewer than 20% attain a bachelor degree within six years of beginning their degree (Parsad & Lewis, 2003). Similarly, remediation has a negative relationship with retention. At two-year institutions, the retention rate for new incoming students assigned to a remedial class was 45.5% compared to 50.7% for those not assigned remediation (Colorado Commission on Higher Education, 2010). At the four-year institutions, the retention rate was 60.1% for those assigned to remediation compared to 77.8% for those not assigned to remediation (Colorado Commission on Higher Education). This low retention rate of remedial students, especially at the four-year institutions, poses an ongoing and serious challenge.

The literature on the impact of underprepared students has largely focused on the policy and under preparedness in the high school setting. Minimal attention has been given to the achievements of those requiring remedial education with regard to persistence, retention, and successful attainment of a degree at a postsecondary institution. The literature generally ignores methods to address this deficit in the university and college setting. This study is designed to address that deficit; it is proposed that this study will look at the methods utilized in a collegiate setting.

Effects on Mathematical Achievement

Arguably, a student's ability to be successful in the field of mathematics is determined by many factors including their inherent intellectual aptitude, learned knowledge, social influences, self-efficacy, and education. Their performance is also correlated to their gender, age, race, and socio-economic status. Even though each of these variables has merit, this review will focus on the different effects of gender, self-efficacy, and supplemental instruction on mathematical achievement.

Gender

The debate over gender differences has gained renewed attention in recent years as researchers attempt to understand the discrepancies that still exist in academia and the work force. Women have surpassed their male counterparts with regard to educational attainment, earning 54% of U.S. doctorates in the non-science/engineering fields awarded in 1997, however, they only earned 23% of Ph.D.s awarded in mathematics and 12% of engineering Ph.D.s (National Science Foundation, 2000). Although more females are working in the science, technology, mathematics, and engineering (STEM) fields, females still earn significantly less than an equally skilled male and the highest paying professions are disproportionately dominated by males (England, 2010), including those in STEM fields (Jones J. , 2010). Gender differences have historically been held responsible for such divergence in academia and career success, but increasing numbers of researchers are invalidating the gender difference hypothesis.

Many argue that females are more likely to have better verbal abilities than males and conversely, males are more likely to have better mathematical skills than females (Skaalvik & Skaalvik, 2004). Researchers contend that soon after children enter elementary school, females begin to fall behind males on standardized assessment (Leahey & Guo, 2001). As shown in

Table 6, results from the 2007 NAEP shows that both during the 4^{th} and 8^{th} grade, the percentage of females both at or above proficient and at or above advanced lag behind their male counterparts, but to no greater extent in 8^{th} grade than 4^{th} grade. Analysis of the NAEP scores between 1990 and 2000 by McGraw, Lubienski and Strutchens (2006) show statistically significant differences in mathematics across gender but that the effect size is very small $(d = .03)$ to small $(d = .20)$.

Table 6
2007 NAEP Mathematics Performance by Gender

	4^{th} Grade		8^{th} Grade	
	Male	Female	Male	Female
At or Above Proficient	41%	37%	34%	30%
At or Above Advanced	7%	4%	8%	6%

Although the NAEP results show females are underperforming males, gender gaps in enrollment appear to be decreasing. The 2008 results of a longitudinal study about high school show that in 1982, a 6.4% gap existed between males and females who enroll in either intermediate or advanced mathematics courses their senior year, 30.4% and 24.0% respectively. By 2004, the gap had decreased to 2.5%, with 51.3% of males, and 48.8% of females enrolling in an intermediate or advanced mathematics course (Ingels & Dalton, 2008).

Recent studies are debunking the commonly accepted hypothesis that males have an advantage over females with regard to mathematical achievement throughout the learning process. Challenging the hypothesis that males, on average, demonstrate higher mathematical abilities than females, Scafidi & Khanh (2010), Else-Quest, Hyde, & Linn (2010), and Hyde (2005) are conversely finding in support of the gender similarity hypothesis "which holds that males and females are similar on most, but not all, psychological variables" (Hyde, 2005, p. 581). Relying on effect size to support the gender similarities hypothesis with "most psychological gender differences are in the close-to zero ($d \leq 0.10$) or small ($0.11 \leq d < 0.35$) range, a few are in the moderate range ($0.36 \leq d < 0.65$), and very few are large ($0.66 \leq d < 1.00$) or very large ($d \geq 1.00$)" (Hyde, 2005, p. 581). In short, questions about gender equity in mathematics still exist but one cannot determine gender to be the cause of that discrepancy.

Self-Efficacy

"Whether you believe you can or you can't, you are right" (Ford). Henry Ford said it well; what we think shapes our reality and may consequently determine our fate.

This perception transcends generations and academia alike. The notion of the nature of intelligence may be divided into two broad theories, entity and incremental theory (Blackwell, Trzesniewski, & Dweck, 2007). Those who believe in entity theory believe that intelligence is an inherent and unchangeable characteristic (Dweck C. S., 1999). Others who believe in incremental theory view intelligence as a trait that can be nurtured over time through hard work (Dweck C. S., 1999). Research has shown that beliefs in self-efficacy influence the academic successes of students (Chen & Zimmerman, 2007) and their selections for university study (Waller, 2006). Even when students on both ends of the continuum show equal intellectual ability, studies show that their theories of intelligence shape their reactions to challenging academic work (Dweck C. S., 2002), (Blackwell, Trzesniewski, & Dweck, 2007). Specifically, Berkaliev and Kloosterman (2009) show a relationship between a student's level of mathematics and their theory of intelligence. In their study, Berkaliev and Kloosterman (2009) compare the perceived beliefs between undergraduate students enrolled in either a developmental or elementary mathematics class. One of the six constructs they studied, effort can increase mathematical ability, showed the mean score to be lower for those students enrolled in a developmental mathematics $(M = 22.4)$ than for those in a collegiate-level mathematics class $(M = 23.4)$. These results imply that undergraduate developmental mathematics students tend to believe they have less control over their intellectual ability than students enrolled in a collegiate-level mathematics class.

If one's plan for post-secondary education is an indicator of self-efficacy then the Trends in High School longitudinal study which began in 1972 provides interesting insight to the reversal of educational attainment trend. In 1972, 16% of males expected to earn a graduate degree as their highest educational level in comparison to only 9% of females. The 2004 data shows that 45% of females expected to earn a graduate degree compared to only 32% of males (Ingels & Dalton, 2008). Moreover, the Education Longitudinal Study of 2002 show that 89.2% of new female high school graduates immediately plan on attending either a 2 or 4 year post-secondary degree, whereas only 79.2% of males have the same plans.

Individual characteristics and how those characteristics relate to one's intelligence will be contested for some time as will the debate regarding whether one's intelligence is malleable or fixed. As a possible indicator of future success, characteristics are just that, indicators. Conversely, enhancing methods of instruction and learning will actively support improved student achievement.

Supplemental Instruction and its Effects on Mathematical Achievement

Challenged with improving student achievement in developmental mathematics, many school systems are turning toward supplemental instruction to support current teaching practices. Supplemental instruction, in its broadest meaning, is a technique, separate from teacher led instruction, which utilizes a variety of technological applications, collaborative learning and tutoring strategies in an attempt to improve student performance. The evaluation of existing research requires a thorough review of supplemental instruction strategies so as to accurately group intervention strategies. Multiple understandings exist for the same terminology and are often interchanged. Supplemental instruction terminology will undoubtedly mature along with the field of educational research.

Computer Mediated Supplemental Instruction

Technological innovations such as software and web based products are currently being utilized to supplement instruction through formative assessments and tutorials. Formative assessment, commonly presented as an in-class worksheet or homework, is a technique which continually assesses the progress of students (Popham, 2008). In comparison, a summative assessment is typically a comprehensive assessment representing the completion of a unit (Popham, 2008). Formative assessments often provide instantaneous feedback and serve as a learning tool, frequently guiding the student to directed learning. Formative assessments not only occur inside the classroom, but outside as well. Contemporary students seek out computer mediated supplemental instruction including online tutorials, instruction modules, and tutoring.

Supplemental instruction via formative assessments and tutorials include interactive components, learner control, and visual stimuli (Angelo & Cross, 1993), all of which are recognized as effective learning strategies. And although the majority of studies include elementary and secondary levels, the intended student enrolled in a developmental mathematics class is the adult learner.

Using pre & post testing, Mendicino, M., Razzaq, L., & Heffernan, N. (2009) compare the achievement of students using traditional paper and pencil homework versus those using the web-based product, ASSISTment. The authors include 4 classes of 5th grade students in a rural community. Although 92 students are enrolled in these 4 classes, only 54 have computers at home therefore the sample consists of two groups of 27 students each. During this four day, counterbalanced experimental design, the groups of students, at different times, act as both the control & experimental group. Students in the experimental group complete the assignment using the software, and those in the control group complete the homework using traditional paper and pencil methods.

Upon attempting the homework using the ASSISTment software, students are given immediate feedback. If answered incorrectly, the program then asked a series of scaffolding questions which require answers in order for the student to continue. In comparison, students who complete the traditional paper pencil assignment are given feedback the following day. When asked questions, the teacher uses the exact hints used in the computer program to ensure consistency. Results of those students who completed both the traditional and web-based assignments show a significant difference in academic performance, $t(27) = 2.04, p < .05$. From a possible 10 points, the mean gain for students using the software is 2.32 whereas those in the control group only show a gain of only 1.14.

In comparison, Jacobson's study (2006) shows no significant effects from completing homework online as compared to the traditional paper and pencil completion. Jacobson's 4 week study is comprised of 8 pre-algebra courses at a public, 4-year University. This quasi-experimental study randomly assigns one control and one experimental class to each of 4 instructors totaling 142 students in the experimental group and 134 in the control group. All students utilize the same textbook, follow the same daily schedule of topics, and are assigned the same homework. Similarly all 276 students take identical departmental examinations on the same dates. Students in the experimental groups are instructed to use the computer support program which accompanies their textbook to complete their homework. Exam scores of the two groups are then compared to determine the effects of using software to complete homework, on academic achievement. As measured by course exams, the study does not find any significant difference between groups, $F(1,266)=.654$. Many possible reasons exist for these non-significant findings, one of which is that only 25% of those students in the experimental group use the online tutorials in addition to completing the homework. And although all of the teachers encourage students to complete homework, only two of the four require homework as part of each student's course grade. Furthermore, the results indicate that the instructor produces a significant effect on the assessment, $F(3,266)=16.66$, $p<.05$ as does the instructor and treatment interaction, $F(3,266)=2.79$, $p<.05$.

Although both the Mendicino et al. (2009) and Jacobson (2006)studies examine the effects of completing mathematics homework via computerized software, they differ on many accounts. The age of students in the Mendicino et al. study is substantially younger than those in the Jacobson study but at that age, when a teacher assigns homework, the majority of students complete it. And, as evidenced by the Jacobsen study, even though students are asked to take more responsibility for their education as they mature, when homework is not required, often they choose not to complete it. Another apparent difference between the two studies is that students in the Mendicino et al. study used the tutorials embedded in the software which "guide students through math problems in much the same way that human tutors do" (Mendicino, 2009, p. 331). Also available are self-contained e-learning instructional modules that provide students with the opportunity to master content prior to learning new material. With so many students not utilizing the optional software in the Jacobsen study, they were essentially diminishing any possible effects caused by the independent variable. Requiring formative assessments and incorporating tutorials within these assessments may provide a wonderful opportunity for students to succeed.

Although not conclusive, the instructional effectiveness of computer mediated supplemental instruction should be further considered for students enrolled in developmental mathematics classes. In addition to computer mediated tutorials, students may also seek supplemental instruction, in-person, from peer and professional tutors.

Peer Tutoring

As educators face the challenge of improving student achievement in mathematics and implementing school, district, state, or federal reforms, demands on their already limited instructional time may also increase. A viable solution may be found by increasing the amount and variety of peer tutoring already occurring in academia. "In a Peer tutoring program, one student teaches another in a school setting" (Allen, 2011). Quality tutoring has long been recognized as a superior instructional method compared to traditional group instruction. Individualized tutoring can adapt to the student's learning style, pace, and level of understanding (Snow, 2005). Instantaneous feedback identifies basic misunderstandings which can be quickly corrected so as to not become ingrained in a student's mind. The reason for student pairings, be it age, ability, or role in the tutoring process, determines the peer tutoring model designation. Peer tutoring models include, but are not limited to, cross-ability, cross-age, and reciprocal peer tutoring.

Research has demonstrated that with proper training, students can successfully tutor other students. There are no stringent tutoring procedures established for peer tutoring; most tutors are, however, engaged in some type of training. Training sessions often include a discussion of goals, behavior and academic problem solving strategies, and appropriate feedback and reinforcement strategies (Miller, Barbetta, & Herron, 1994). Tutors become models of appropriate behavior, organizing work, asking questions, demonstrating self-management, encouraging social interaction, and facilitating better study habits (Gordon, Morgan, O'Malley, & Ponticell, 2006). Strikingly, student tutors often benefit as much or more than their tutees (Maheady & Gard, 2010) As such, peer tutoring is often an effective educational strategy for classrooms of diverse learners because it promotes student engagement (Gordon et al.), academic gains (Maheady & Gard), and the total amount of academic learning time available (Gordon et al.). Peer tutoring may therefore help teachers manage a diverse student population and limited instructional time, all while improving student achievement in mathematics.

Cross-age and Cross-ability peer tutoring models are often used interchangeably in research studies. Cross-Age Tutoring is a peer tutoring approach that joins students of different ages, with older students assuming the role of tutor and younger students assuming the role of tutee (Scott-Little & Valentine, 2004). Although age and ability are highly correlated variables, cross-ability peer tutoring better identifies most studies termed cross-age studies. The differentiation is a result of the dominant reason for their pairing, either ability or age and its distinction is essential for understanding the generalizability of a study. "In cross-ability tutoring, the student acting as the tutor has already attained greater mastery of the subject or material being taught" (Allen, 2011). Cross-age tutoring has often resulted in significant academic and interpersonal growth among both older and younger learners in a wide range of subjects (Kalkowski, 1995).

Research suggests that cross-age tutoring is more advantageous than reciprocal peer tutoring (Topping, Miller, Murray, Henderson, Fortuna, & Conlin, 2011). Reciprocal tutoring is when "students of the same age or ability take turns being the tutor" (Allen, 2011), is particularly beneficial in non-homogeneous classrooms because it allows teachers to address a wide range of learning needs while simultaneously engaging all students (Kamps, et al., 2008). Furthermore, the collaborative learning aspect of the strategy encourages positive social interaction between students in a classroom. By including traditional instructional strategies along with peer tutoring, teachers may be able to better utilize the ability differences inherent in an inclusive classroom to promote accessible and successful learning for all.

The empirical literature on the effects of tutoring varies greatly based on content area, program length, tutor and tutee age and ability. Research outcomes also vary greatly and include academic success of individual courses, institutional retention, student attitudes and anxiety level. The vast majority of existing literature focuses on students at the elementary or secondary levels, with limited studies at the community college and even less at the university level.

Even though the number of methodically sound and rigorous empirical studies specific to tutoring developmental mathematics students at the post-secondary level is extremely limited, the impact of tutoring on student achievement has been widely debated in the literature.

Through a methodologically sound, quasi-experimental study, Allsopp (1997)examines the effectiveness of classwide peer tutoring on mathematics problem solving skills in a heterogeneous, eighth grade, pre-algebra class. The author reports that classwide peer tutoring is an effective instructional technique, but that it is no more effective than independent learning. Three Florida middle schools, including 14 different general mathematics classes and 262 students participated in the study. The four participating teachers each had more than 10 years of experience and attended an inservice for the curriculum and classwide peer tutoring procedures. Subsequently, the teachers in the experimental group then trained their "students to use the appropriate tutoring behaviors necessary for assisting others in learning the academic/cognitive skill" (Allsopp, 1997, p. 368). During each 30 minute session, students each take a turn acting as both tutor and tutee. These sessions occur 2 to 4 times per week for a total of 16 to 18 sessions.

Student characteristics between the treatment groups were examined using chi-square analyses and find a significant difference between those students who are identified as at-risk, compared to those are not, $(t = -5.5891, 260, p < .001)$. The results of the repeated measures ANOVA indicate that both classwide peer tutoring and independent student practice are effective learning strategies for learning problem solving skills, $F(1{,}258) = 768.25, p < .001$, but that one was no more effective than the other. At-risk students demonstrated slightly higher gain scores than those students not characterized as at-risk for failure.

Although the age group is significantly younger than the target population, the content is in line with the desired material to be covered in a developmental mathematics class. The high quality of Allsopp's peer tutoring study is to be respected and emulated, specifically with regard to the cited methodological considerations and implementation practices. Although limited studies exist with regard to peer tutoring, the theory that peer tutoring is an effective instructional technique has merit. But, peer tutoring is not the only effective instructional technique. Similar studies support cross-age tutoring as another effective instructional technique.

In contrast to peer tutoring, cross-age tutoring links students of different ages and or abilities such that there is a clear delineation between tutor and tutee. Although there are no stringent tutoring procedures established for cross-age tutoring, most tutors participate in some type of training. Often, these training sessions include a discussion of goals, behavior and academic problem solving strategies, and appropriate feedback and reinforcement strategies (Miller, Barbetta, & Heron, 1994). Limited evidence exists with cross-age tutors in developmental mathematics courses.

Many cross-age tutoring programs are voluntary, especially in post-secondary education where attendance at the class itself is often not required. Wright, G., Wright, R., & Lamb, C. (2002) developed a quasi-experimental study to examine the effectiveness of a cross-age tutoring program for students enrolled in a developmental mathematics program at a southern state university. Although weak with regard to design, implementation, and analysis, results of this study are promising nonetheless. Wright et al. followed three different instructors for two semesters, comparing the achievement of students who attend workshops led by cross-age tutors against student achievement of students prior to implementation of the cross-age tutoring program. Attendance at any of the 25 sessions was not required and for the purposes of the study, a student who attended at least three sessions was considered a participant. As shown in Table 7, descriptive statistics show greater mean exam scores for those students who participate in supplemental instruction workshops held by cross-age tutors, as compared to those non-participants.

Table 7
Wright Study: Mean Exam Scores for by Condition

	Exam II	Exam III	Final
SI Participants	73.0	65.3	59.6
Non-Participants	56.8	49.7	48.8

Although the methodology, implementation, and analysis are extremely weak, the concept is representative of the countless informal studies conducted by faculty members worldwide to quickly ascertain feedback on classroom interventions.

Two recent studies by Fayowski and MacMillian (2008) and Parkinson (2009) support the use of cross-age peer tutors in classes which require higher order mathematics skills. In comparison to cross-age tutoring focusing on developmental math, Fayowski and MacMillian (2008) examined the effectiveness of a cross-age peer tutor in a first year calculus course for non-majors. Initial analysis of three groups, those student in classes without the option of SI, and classes with the option of SI divided by students who chose to either participate in SI or not, provides evidence of statistically different grades $(F = 26.8, p < 0.0005)$. Tukey post hoc testing reveals that the only difference is between the SI group and the other two groups, with the SI participants outperforming the other two groups. Compensating for issues of biases, including self-selection and gender, Fayowski conducted further analyses. Results show that the SI/gender interaction is non-significant, that is, there is no differing effect of the treatment for males and females. Additionally, significant differences in achievement still exist after correcting for motivation & gender, that is, participation in SI improved grades even after accounting for ability/motivation, and gender.

Similarly, Parkinson (2009)implemented Peer Assisted Learning Strategies (PALS) for first year students pursuing a degree in biotechnology at Dublin City University. Scores on the mathematics diagnostic pretest were not significantly different for the tutored group ($M = 57.8\%$) than for the non-tutored group ($M = 51.9\%$). However, the slightly higher score for those students in the tutoring group may overstate any realized effects. After one semester, significant differences between the two groups emerged. Students who participated in the cross-age tutoring groups had a significantly ($p = .03$) higher pass rate ($M = 88.9\%$) in Mathematics than the non-tutored students ($M = 57.1\%$). Similarly, the retention rate of students in both the program and the University were significantly greater. For those that earned high marks, no significant difference was found between those who participated in the supplemental instruction ($M = 45\%$) versus those who did not participate ($M = 43.2\%$). When the effect of pretest scores was controlled for there was still a significant effect ($p = .034$) of tutoring on mathematics achievement.

Tutoring Conclusion

Contemporary research findings support earlier conclusions that peer and cross-age tutoring are effective methods for increasing mathematics achievement in developmental courses. Additionally, some of the more recent studies suggest that supplemental instruction may support subjects which rely on higher order thinking skills as well. The vast quantity of educational research is overwhelming; not that it is intimidating but frustrating since hundreds of articles must be scoured to yield a single methodologically sound study. The fact that each study is unique with regard to student characteristics, variations in terminology, supplemental instruction methods, or another variable highlights the importance of continuing research. Narrowly focused, additional research is necessary to investigate the impact that supplemental instruction has on student achievement in developmental mathematics. On a broader scale, improved research methods and more consistent terminology in the field of education will improve the practicality of significant findings. Not until then will faculty be able to more consistently implement pertinent research findings in their classroom.

Frequency of Instruction

In an effort to increase student learning and achievement, many primary and secondary school systems nationwide are examining alternatives to the structure of the traditional school day (Canady & Rettig, 1995). In comparison to a traditional year long course, alternative scheduling exists in many forms including block scheduling, mini-semesters, quarters, and trimesters. Although considerable research exists to suggest the possibility of alternative scheduling at the middle (Jenkins, Queen, & Algozzine, 2002), and secondary levels (Biesinger, Crippen, & Muis, 2008), alternative scheduling research at the postsecondary level is severely limited.

Block Scheduling

At the secondary level, block scheduling has become a very controversial topic with proponents on both sides of the issue (Zepeda & Mayers, 2006). Block Scheduling generally refers to extended learning period. Traditionally, a class may last between 45 and 60 minutes; in the block scheduling format, a class may last between 85 and 100 minutes (Biesinger, Crippen, & Muis, 2008). Some formats, like the 4x4 block scheduling format, increase the amount of time students spend in a particular class both per day and per week thus condensing a class which once spanned a year into one semester (Canady & Rettig, 1995). Other block scheduling formats increase time per session, but alternate days to which they occur thus the difference in time from the beginning of the class to the end is the same (Jenkins, Queen, & Algozzine, 2002).

Advocates of the block system suppose that longer class periods will translate into higher student achievement compared to traditional yearlong courses. Lewis, Dugan, Winokur, and Cobb (2005) report that students from the 4x4 block scheduling group outperformed the traditional scheduling group. Advocates also claim that block scheduling translates into more student-centered instruction. The results, however, are inconclusive. For every study which finds block scheduling increases student-centered instruction (Veal, 2000), another study concludes that teacher-centered instruction still dominates the classroom (Jenkins, Queen, & Algozzine, 2002).

Opponents of block scheduling report that student achievement is higher with yearlong academics compared to condensed courses. In *An objective look at math outcomes based on new research into block scheduling*, Wronkovich (1997) found that students studying in a block schedule performed significantly lower on mathematics assessments compared to those under a traditional scheduling. Similarly, the results of a 2008 study show that students who were enrolled in a year-long calculus course scored significantly higher on the advanced placement (AP) Calculus exam than students completing the semester long course (The College Board, 2010).

Because block scheduling increases the time for each class meeting, effectively, the number of class meeting diminishes thus minimizing opportunities for learning. This effect, known as the Spacing Effect may be underlying many of the results of clock scheduling.

Postsecondary Scheduling

Although the structure and frequency of instruction may be a predictor of success, literature pertaining to course scheduling at the postsecondary level is scarce. Additional terminologies that also may be used to describe differences in scheduling include distributed learning and the spacing effect. In the field of psychology, the spacing effect is well-documented and been researched extensively yet its relationship to education and specifically mathematics education is very limited. At the postsecondary level, scheduling of a three credit semester hour course traditionally may be offered three times a week for 50 minutes per class or twice a week for 75 minutes per class. Recently, though, there has been a growing trend to offer postsecondary classes in a condensed format. Like block scheduling, these condensed formats vary widely but combines at least one of two deviations to the traditional schedule. One variation includes increasing the number of hours per day while keeping the number of weeks constant. Alternatively, reducing the number of weeks per course thus increases the number of hours per day, the number of days per week, or both.

The Spacing Effect

The spacing effect, a well-documented effect on memory (Cepeda, Coburn, Rohrer, Wixted, Mozer, & Pashler, 2009) denotes that "for a given amount of study time, spaced presentations yield substantially better learning than do massed presentations" (Dempster F. N., 1988, p. 628). Researchers (Bahrick & Hall, 2005) hypothesize an explanation for the positive effects of spacing on learning; when study activities are spaced in time, students may notice that they have either forgotten or don't understand some of the material. A single class session may not afford the student enough time to realize which material is difficult to recall or understand. Students may then focus on weakly learned material during a subsequent class. Smith and Kimball (2010) also conjecture that, in addition to error correction, the spacing effect may also strengthen initially correct responses and increase confidence.

Students at the postsecondary level often choose their schedule from a variety of times and choices. Results of studies involving metacognitive control over the distribution of practice contain conflicting results. Son's (2004) results indicate that students tended to prefer spaced practice for easy items, but their tendency to choose massed practice increased as items became more difficult. Investigating the spacing effect further, Benjamin and Bird (2006) obtained just the opposite results from Son. Working with factors from each study, Toppino, Cohen, Davis, and Moors (2009) corroborated Benjamin and Bird's (2006) results. These studies imply that massed or condensed classwork may be appropriate in some applications. For difficult subjects, however, distributed learning may provide a better situation for learning.

Variations to traditional scheduling at the primary, secondary, and postsecondary academic institutions are certainly changing the manner in which students learn. Also with certainty, these academic institutions aspire to provide students with the greatest likelihood of success. More research is needed to investigate the effects of spacing and distributed learning on achievement in academia.

Conclusion of Literature Review

The literature highlights a great need for higher quality education for the children in the United States, displaying time and time again that American students are lagging behind learners in other countries. This is not due to disinterest or lack of effort. The vast majority of schools in the United States are looking to improve the learning experience of its students; two methods are the use of peer tutors and the redistribution of classes. Neither topic is revolutionary yet they are also not widely accepted in academia. The literature suggests that peer tutoring may provide benefits to both the tutor and tutee. Additionally, peer tutors may also provide economic benefits to the school; student employees who function as peer tutors can reduce the strain on stressed budgets. Economic constraints may also drive schools to examine alternatives to current scheduling tactics. But many schools, colleges, and universities are attempting to restructure the school day in an effort to increase student learning. Distributed learning or the spacing effect, as it's referred to in the field of psychology, is one technique which is being examined to help assess how curriculum is offered to students.

The literature search revealed a lack of literature specifically related to the spacing effect and mathematics as well as the use of peer tutors at the postsecondary level. This study is focused on examining the effect of a cross-ability peer tutor and frequency of instruction on student achievement in a postsecondary developmental mathematics classroom.

CHAPTER 3: METHODOLOGY

The intention of this study is to investigate the relationships between four factors, a cross-ability peer tutor, frequency of instruction, gender, and mathematical achievement for students enrolled in a developmental mathematics classroom. More broadly, though, the purpose of the study is to improve the performance of low-performing students in a high-risk class by providing students with an environment that fosters learning.

Philosophical Paradigm

The experimental design or "paradigm determines the type of questions that will be asked and how they will be answered" (Morgan, Gliner, & Harmon, 2006, p. 14). Two main paradigms within educational research, quantitative and qualitative often form the foundation of a researcher's perspective. The paradigms, however, need not be mutually exclusive. Blending the two paradigms, "so that one paradigm sets the stage for or leads to the other paradigm the approach is called mixed methods" (Gliner, Morgan, & Leech, 2009, p. 9). It is this, the mixed methods philosophical approach, which is utilized in this study.

The quantitative paradigm emphasizes the scientific method and asserts that empirical scenarios representing real events can be analyzed and explained (Creswell J. W., 2005). Quantitative research methodology therefore emphasizes experimentation that minimizes external variables. Believing that experimentation can explain relationships between variables, one aspect of the philosophical approach follows a quantitative approach. This quantitative approach alone, however, will not provide a comprehensive understanding of the experiences that participants face. The qualitative paradigm will serve to "follow up quantitative research and help explain the mechanisms or linkages in causal theories or models" (Creswell J. W., 2007, p. 40) Through the analysis of interviews and the emergent data, the qualitative approach attempts to construct a deeper and more complete meaning of the experiences of students, tutors, and faculty engaged with a developmental mathematics course.

Research Approach

Quantitative research may be categorized by three research methods, experimental, non-experimental, and descriptive (Gliner, Morgan, & Leech, 2009). Experimental designs occur when one, or multiple, interventions are conducted on different groups of participants to assess whether the interventions affect the dependent variable. When interventions cannot be conducted and the relationship or association between variables is desired, non-experimental designs may be more appropriate. Lastly, if the purpose of the research is to simply describe the data then a descriptive approach would be the most appropriate quantitative technique. Similar to the philosophical paradigm, a study may be comprised of more than one research approach. This study, which contains both experimental and non-experimental approaches, is aptly termed complex (Gliner, Morgan, & Leech).

Research Design

When a random assignment of participants to groups cannot be accomplished, then the research design is quasi-experimental (Gliner, Morgan, & Leech, 2009). More specifically, however, the effect of frequency of instruction on developmental mathematics student achievement was investigated through a quasi-experimental research design. Neither the registrar nor the students were aware of the experimental conditions being imposed on the class at the time of registration; all students registered for a class which was scheduled to meet for two hours, twice per week, for eleven weeks. The assignment of a first year student to a condition begins as a random assignment by the registrar, and the great majority of students remain as assigned. Students, however, have the ability to self-register and alter their schedule at will. Because the researcher uses intact groups and the researcher has control over the independent variable, the research design can be classified as a strong pretest-posttest quasi-experimental design (Gliner, Morgan, & Leech).

In an attempt to further understand and support the quantitative results, qualitative research methods are employed. Shank (2006) views qualitative research as “a form of systematic empirical inquiry into meaning” (p. 4). Shank (2006) continues, however, to suppose that the definition of qualitative research can be as varied as the person defining it. Through the use of both panel and individual interviews, a basic interpretative qualitative analysis helps to uncover the experiences for the students, cross-ability peer tutor and instructor.

Evaluation of the Quality/Validity of Methods Proposed for this Study

Through random assignment of individuals to an intervention, experimental design attempts to ascertain whether a causal relationship exists between the intervention and another variable. Quasi-experimental design differs in that it compares intact groups, rather than randomly assigning individuals (Morgan, Gliner, & Harmon, 2006). Quasi-experimental designs, however, often present additional threats to both the internal and external validity compared to a true experimental design (Creswell J. W., 2005). Prudent planning minimizes these threats and thus increases the validity of this study.

Threats to Internal Validity

Campbell and Stanley (1963) defined internal validity as "the basic minimum without which any experiment is uninterpretable: did in fact the experimental treatments make a difference in this specific experimental instance?" (p. 5). To maximize the internal validity, this study utilizes the two broad categories shaped by the contemporary researchers, Morgan, Gliner, & Harmon (2006), equivalence of groups, and control of extraneous experience and environmental variables.

In research that compares differences among groups, it is imperative then that the groups are equivalent prior to the introduction of the intervention (Morgan, Gliner, & Harmon, 2006). In order to minimize differences among groups, neither the registrar nor students registering for these classes were aware of the interventions at the time of registration. There is no reason to suggest that one group would experience significant differences with regard to selection, attrition, or regression. And, although the study does not employ a random assignment of participants to an intervention, a random assignment of treatment to the intact groups is utilized. Furthermore, analysis of covariance is calculated for the data thus ensuring similar groups.

Effects of extraneous experiences and environmental variables which may affect one group more than another and should not be ignored. An educational setting is not a controlled laboratory setting and threats related to the intervention exist regardless of whether the study is a true or quasi-experimental. Unavoidably, discussion between students in different interventions certainly occurs. As a result, students may learn about and utilize the offered tutoring services on campus. Students who seek tutoring assistance outside of the scheduled class time may experience gains not caused by either the cross-ability tutor or the frequency of instruction. Qualitative data collected through the panel interviews provides valuable information on this topic. Undoubtedly, students will mature at different rates than each other. In an attempt to minimize a maturation effect, student data is collected over the entire academic year.

Additional threats to internal validity exist with regard to the instrument and its assessment. For the purpose of this study, each assessment question was dichotomously scored as either correct or incorrect. As a result, inter-rater reliability is very high. Independently from this study, the faculty member does employ an alternate grading strategy for the student's academic grade.

With the intent of conducting a meaningful inquiry, a researcher must carefully consider how to construct their study so that cause and effect relationships, should they be present within the analysis, are best inferred. This research controls for most of the threats to internal validity by random, or at least mostly random, assignment of participants to the intervention.

Threats to External Validity

Campbell & Stanley (1963) explain external validity as a "question of generalizability: to what populations, settings, treatment variables, and measurement variables can this effect be generalized" (p. 5)? The contemporary authors, Morgan, Gliner, & Harmon (2006), take a proactive perspective and focus on designing the study so that "the actual sample of participants is representative of the theoretical or target population" (p. 127). To accomplish this, Morgan, Gliner, & Harmon (2006) suggest researchers consider four traits when designing their study; these include the apparent theoretical population, the accessible population, the sampling design and selected sample, and the actual sample.

Although the interaction between selection and treatment can be controlled for in experimental designs, educational environments do not allow for such control. This study, however, is a strong, quasi-experimental design because of the random assignment of the intervention to the intact groups. The students are all enrolled in a private, not for profit, degree granting university located in an urban city in the western United States; these facts alone limit the study's scope. An artificial setting or a student's knowledge that he is participating in a study may create a reactive arrangement and subsequently influence the data, but this was not observed in this study. During this study, students neither attempted to switch classes nor sought tutoring at higher rates than during previous terms. Students are aware of faculty autonomy and variations amongst faculty members are common. The assessments are integrated into the curriculum with the dichotomous data for this study being collected separately and often unbeknownst to students. These conditions are designed to minimize the threat of a reactive arrangement.

The seminal authors, Campbell & Stanley (1963) as well as contemporary authors, Morgan, Gliner, & Harmon (2006) present many important validity concerns for a researcher to consider while designing research. Although both sets of authors present recommendations from different perspective, their intent is indistinguishable, to assist researchers in developing more robust research.

Efficacy of Proposed Methodology to Address the Research Questions

Both the research setting and selection of participants are conducted so as to provide value to the proposed methodology and therefore preserve the ability to address the research questions.

Research Setting

With the intention of furthering the understanding of remedial mathematics at the university level, it is important that the research setting chosen be a university. The university chosen is a private, not for profit, degree granting university located in an urban city of the western United States. The estimated annual enrollment is 1,500 students with 40% of incoming students placing into a developmental mathematics class. The class size for developmental classes at this university is capped at 30 students.

The class was taught by a highly qualified and successful, male, full-time faculty member. Administration arranged for one faculty member to teach the vast majority of developmental classes for one year and the faculty member agreed to teach both the experimental and control sections for this experiment. Traditional classes taught between 8:00 a.m. and 6:00 p.m. were included in this study; evening, weekend, or condensed classes were not included. Although unaware of the specific research questions, the faculty member was made aware of the four classroom constructs so that he could accurately prepare syllabi and lesson plans. Similarly, one male student employee who has worked in the tutoring center on campus for three years served as the in-class cross-ability peer tutor during his normally scheduled tutoring hours. The cross-ability peer tutor had been trained in effective tutoring techniques, including listening, questioning, and instruction. Utilizing only one instructor and peer tutor throughout this study reduces possible teacher effects and helps clarify the influence of the intervention on mathematical achievement.

Participant Selection and Sample Size

The quantitative aspect of this study focuses on the quasi-experimental intervention which occurred during the 2009 and 2010 academic years for students enrolled in the developmental mathematics class at this university. The population reaches all traditional developmental mathematics students at the university. In an attempt to minimize teacher effect, only one faculty member was utilized and this faculty member taught no less than 90% of all developmental mathematics classes during the time of the study. At the time of registration, students were not aware which faculty member is assigned to each class thus further minimizing faculty effect. It was anticipated that up to 25% of the originally enrolled students would be removed from the study due to course repetition and course non-completion. With all independent variables applied to the total sample, the minimum sample size of twenty in any subgroup further strengthens the internal validity of the study.

The selection of participants for the qualitative aspect of the study is considered to be purposeful. Creswell (2007) states that the researcher “selects individuals and sites for the study because they can purposefully inform an understanding of the research problem and central phenomenon in the study” (p. 125). The minimum sample size of five students from each intervention strategy was sufficient to reach saturation of the collected data.

Data Collection

Data collection occurred via three processes; demographic data collected from the registrar, mathematical achievement collected from the instructor, and interviews with participants conducted after the conclusion of the class.

The registrar provided data including gender and course attempts for all the students enrolled in each class. These data were purposefully acquired from the registrar because students may not truthfully self-disclose repetition of a developmental mathematics course. Along with experimental design characteristics, the faculty member teaching the courses submitted student gender and exam scores to the researcher.

To collect student scores on mathematical achievement, each of the four independent intervention groups were first given a 40-item pretest previously determined to represent the minimum skill level necessary to study college level mathematics. Calculators were allowed on this, and all subsequent assessments. Each group was then taught the same content and assessed with identical instruments throughout the term. At the conclusion of the term, each student was then post-tested with the same 40-item test on mathematical skills given at the beginning of the term; students are not made aware that the assessments are identical. The primary reason for using repeated measures is to measure the learning effect in the developmental mathematics classroom. To minimize the carry over effect from one assessment to the next, after all they are identical assessments, the pre and post-tests are given eleven weeks apart. Additionally, although the individual problems are discussed in class, the pretest is not returned. These methods should help to minimize threats related to administering the assessment.

Using a variation of the standardized open-ended interview approach in which "all interviewees are asked the same basic questions in the same order" (Patton M. , 2002, p. 349), panel interviews with students were conducted in order to collect data about student experiences, importance, and meanings. Experiences and associations from the cross-ability peer tutor and instructor were also collected via individual interviews with each of them. According to Patton (2002), the purpose of an interview is to "enter into the other person's perspective" (p. 341) and "find out from them the things we cannot directly observe" (p. 340). During the interviews, open ended questions were presented so to allow all participants to "take whatever direction and use whatever words they want to express what they have to say" (Patton M. , 2002, p. 354). In order to address the research questions which inquire about student perceptions with regard to frequency of instruction and the participation of the cross-ability peer tutor, each panel was asked the same set of questions, in the same order. Question 3 will be omitted for the panels of students who did not have a cross-ability peer tutor in the classroom.

Interview Questions for Student Panels

1. With respect to the basic mathematics class you have completed at this university, will you please describe your experience with your attendance for the class?
2. With respect to the basic mathematics class you have completed at this university, will you please describe your experience with your use of class time? What occurred during class?
3. With respect to the basic mathematics class you have completed at this university, will you please describe your experience with the tutor during class time?

4. With respect to the basic mathematics class you have completed at this university, will you please describe your experience with whether you thought the class was a good use of your time?
5. With respect to the basic mathematics class you have completed at this university, will you please describe your experience with your how often you worked on class material outside of class?
6. With respect to the basic mathematics class you have completed at this university, will you please describe your experience with the type of material you worked on outside of class?
7. With respect to the basic mathematics class you have completed at this university, will you please describe your experience with the tutor outside of class?
8. How would you describe your overall experience of the basic mathematics class you have completed at this university?
9. Would you like to discuss any other aspects of the basic mathematics class that you think impacted your learning?

The cross-ability peer tutor and faculty member designated to teach the classes were similarly interviewed, but their questions were tailored to their position.

Interview Questions for the Cross-Ability Peer Tutor

1. With respect to the basic mathematics course you tutored at the University, will you please describe your overall experience?
2. With respect to the basic mathematics class you tutored at the University, will you please describe your experience with tutoring students during class?

2.1. Did you observe any difference between students enrolled in a class that met once per week and those who met twice per week?

3. With respect to the basic mathematics class you tutored at the University, will you please describe your experience with tutoring students outside of class?

   3.1. Did you observe any difference between students enrolled in a class that met once per week and those who met twice per week?

4. With respect to the basic mathematics class you tutored at the University, will you please describe the type and/or quantity of questions students asked you?

   4.1. Did you observe any difference between students enrolled in a class that met once per week and those who met twice per week?

   4.2. Did you observe any difference in student willingness to ask for or accept help between those enrolled in a class that met once per week and those who met twice per week?

5. Would you like to discuss any other aspects of the class that you think impacted learning for those students enrolled in the developmental math class?

Interview Questions for the Faculty Member

1. With respect to the basic mathematics course you teach at this University, will you please describe your overall experience?

2. With respect to the Basic Mathematics class you teach at this university, will you please describe your experience with the cross-ability peer tutor?

   2.1. Did you find the student helpful?

   2.2. Did you observe students interacting differently with the tutor than they do with you?

2.3. Do you think similar effects would have occurred if the class size were simply halved?

2.4. Will you request another cross-ability peer tutor from the Center for Academic Support?

3. With respect to the Basic Mathematics class you teach at this university, will you please describe your experience with student-faculty interactions during class

   3.1. Did you observe any interaction differences between those students enrolled in classes that met once per week and those who met twice per week?

4. With respect to the Basic Mathematics class you teach at this university, will you please describe your experience with student-faculty interactions outside of class?

   4.1. Did you observe any interaction differences between those students enrolled in classes that met once per week and those who met twice per week?

5. With respect to the Basic Mathematics class you teach at this university, will you please describe your experience with the type and/or quantity of questions students asked you.

   5.1. Did you observe any difference in student willingness to ask for or accept help between students enrolled in classes that met once per week and those who met twice per week?

6. Would you like to discuss any other aspects of the class that you think impacted student learning?

Variables and Method for Analysis

Quantitative Data Analysis

This complex study includes a research design with three independent variables, each with two levels. As detailed in the literature review, the spacing effect and cross-ability tutoring are two independent interventions which may positively impact student learning. Implementation of the spacing effect keeps the total classroom time constant, regardless of which group the student is enrolled. The second independent variable, a cross-ability tutor, is also dichotomous; either the tutor participates in the class, or does not. These two independent variables sketch the framework for the four instructional methods, as depicted in Table 8. Analyzing the results of this simple 2x2 intervention may provide insight into better teaching and scheduling strategies.

Table 8

Summary of Instructional Methods

	Frequency of Instruction	
Tutor Assistance	Once Per Week	Twice Per week
Cross-Ability Tutor	Once Per Week, Cross-Ability Tutor	Twice Per Week, Cross-Ability Tutor
No Cross-Ability Tutor	Once Per Week, No Cross-Ability Tutor	Twice Per Week, No Cross-Ability Tutor

The inclusion of a third independent variable, gender, adds another dimension to this study thus creating a 2x2x2 model. Together, the three dichotomous independent variables form eight regions within a cube whose axes are tutor assistance, frequency of instruction and gender. Visualizing the representation of the fourth factor, time, may be accomplished with two cubes; the first cube represents the pretest, and the second cube the posttest, with each cube containing the eight aforementioned regions.

The dependent variable, mathematics achievement, is objectively and repeatedly measured by identical pre and posttests. Specifically, the data includes a criterion-referenced, quantitative measure of individual performance represented by the number of correctly answered questions on a forty question, multiple choice assessment. Hence, the study is considered a 2x2x2x2 mixed design with a repeated measure on the last factor.

Qualitative Data Analysis

In addition to the quantitative component, a sequential explanatory mixed method design relies on a follow-up qualitative element. A basic interpretive qualitative study utilizes “interviews, observations, or document analysis” (Merriam, 2002, p. 6) in an attempt to “identify recurring patterns or common themes” (Merriam, 2002, p. 7). This study uses panel interviews as well as individual interviews to collect this type of data. Responses from the students, faculty, and cross-ability peer tutor were transcribed and subsequently analyzed for common perceptions of the learning environment.

Conclusion

Laying the foundation for a quality study is a comprehensive methodology which details the research paradigms, methods, and designs. Careful attention to limitations and delimitations determine the depth and breadth to which a study may apply. The results of this study are supported by a strong quasi-experimental research design and careful attention to internal validity. Potential results, however, may be unique to the university; caution should be exercised when generalizing this study. The methodology supports the intent of this study to investigate the relationships between a cross-ability peer tutor, frequency of instruction, gender, and mathematical achievement for students enrolled in a developmental mathematics classroom.

CHAPTER 4: DATA ANALYSIS

The overarching purpose of the study was to examine the impact of instructional methods on mathematical achievement in a collegiate developmental mathematics classroom. Additionally, this study is designed to garner detailed, meaningful insight into the factors that may influence mathematical achievement. The means by which to attain this information is separated into two parts, a quantitative and qualitative component. First, the quantitative differences that may exist between frequency of instruction, the participation of a cross-ability peer tutor in the classroom, and gender on mathematical achievement are presented. Second, the results of the qualitative study which focuses on the experiences of the student, cross-ability peer tutor, and instructor are presented to gather more detailed insight than the quantitative analysis alone could provide.

Quantitative Analysis

The effects of four instructional methods on developmental mathematics achievement were investigated using a strong quasi-experimental research design (Gliner, Morgan, & Leech, 2009). The study contains four independent variables, three between-groups independent variables and one repeated-measures independent variable. The three between-groups independent variables, participation of a cross-ability tutor in the classroom, frequency of instruction in which the class meets either one hour twice a week or two hours once per week, and gender are all dichotomous. All students are measured with identical assessments at the beginning and end of the term; the fourth independent variable, time, is therefore a repeated-measure independent variable. Since the students were in intact groups, the design is a nonequivalent group design with a pretest and posttest (Gliner, Morgan, & Leech). Furthermore, Gliner, Morgan, and Leech suggest that a mixed ANOVA will be the best analysis technique for this design. More specifically, the analysis is conducted using a repeated measure 2x2x2x2 mixed ANOVA. The data analysis technique is simplified into three steps, testing for assumptions, omnibus analysis, and any essential subsequent post hoc analysis. The statistical software package, SPSS 18.0 was utilized to answer the quantitative research questions.

Assumptions

The assumptions for a mixed ANOVA include normality, homogeneity of variances, and homogeneity of covariances. The data are tested for univariate normality for all observations. The posttest scores show a significant skew with a *z*-score of skewness of -2.361. Normalized skewness statistics show only minor deviations from acceptable limits; univariate normality is therefore assumed. Visual inspection of histograms and normal Q-Q plots confirm normality. Levene's test for equality of error variances is not significant for the pretest or posttest, $F(7,199) = 1.278, p = .26$ and $F(7,199) = .809, p = .581$ respectively, indicating that the variances are homogeneous. Box's test of equality of covariance matrices, $M = 37.968, F(2195593.07) = 1.745, p = .018$, however, is significant, signifying that the homogeneity of the covariance matrices is violated in at least one of the combinations of the between-subjects factors. Even though the result of Box's test is significant, with a data set comprised of more than 200 entries, it is quite possible that "Box's test could be significant even when covariance matrices are relatively similar" (Field, 2009, p. 604). Sphericity denotes the equality of variances of differences between treatment levels; since the measure is repeated only twice, sphericity does not need to be examined (Field, 2009).

Descriptive Statistics

A total of 207 students, 113 females and 94 males, completed the study in entirety including the pretest ($M = 17.61, SD = 5.593$) and post-test ($M = 28.09, SD = 5.424$) assessments. As shown in Table 7, the student distribution for the frequency of instruction was relatively equal with 91 students completing the class that meeting once per week and 116 students completing the class that met twice per week. Pretest scores for those students who met once per week ($M = 17.34, SD = 5.694$) are comparable to those who met twice per week ($M = 17.83, SD = 5.527$). The posttest scores of those who met once per week ($M = 25.65, SD = 5.208$) are more than 10% lower than those students who met twice per week ($M = 30.01, SD = 4.801$), equating to a mean of 64% and 75% respectively. The distribution of gender across instructional methods is relatively equal with 50 (24%) females and 41(20%) males meeting once per week. Similarly, 63(30%) females and 53 (26%) males met twice per week. A further breakdown of the descriptive statistics, delineated by frequency of instruction, involvement of a cross ability peer tutor in the classroom, and gender is shown in Table 9. The gender differences shown in this sample are proportional to the gender differences of the student population at the study site.

Table 9

Means and Standard Deviations for Developmental Mathematics Achievement Partitioned by Instructional Format, Gender, Frequency of Instruction, and Time

			Prettest		Posttest	
		N	M	SD	M	SD
Once Per Week						
Gender	Cross-Ability Peer Tutor					
Male	No Tutor	21	17. 52	4.589	25.43	4.567
	Tutor	20	18.40	6.021	27.60	5.586
	Total	41	17.95	5.287	26.49	5.144
Female	No Tutor	30	17.50	5.692	25.60	4.875
	Tutor	20	15.85	6.491	24.00	5.666
	Total	50	16.84	5.525	24.96	5.210
Total	No Tutor	51	17.51	5.217	25.53	4.705
	Tutor	40	17.13	6.313	25.80	5.845
	Total	91	17.34	5.694	25.65	5.208
Twice Per Week						
Gender	Cross-Ability Peer Tutor					
Male	No Tutor	22	18.14	5.357	31.68	3.847
	Tutor	31	18.61	6.190	29.32	5.095
	Total	53	18.42	5.809	30.30	4.725
Female	No Tutor	26	18.04	4.911	30.35	4.454
	Tutor	37	16.84	5.525	29.35	5.192
	Total	63	17.33	5.273	29.76	4.888
Total	No Tutor	48	18.08	5.065	30.96	4.197
	Tutor	68	17.65	5.861	29.34	5.110
	Total	116	17.83	5.527	30.01	4.801

Effects Analysis

The effects analysis directly references the first eight research questions, specifically, whether there is a difference or interaction between the independent variables including the frequency of instruction in which students either meet once or twice per week, participation of a cross-ability peer tutor in the classroom, gender, and the repeated measure of mathematics achievement. With this exploratory analysis, all effects are reported as significant at $p < .05$. The planned comparisons of four independent variables produces four main interactions, six pairwise interactions, four triple interactions and one quadruple interaction.

As shown in Table 10, the mixed ANOVA source table, the results indicate two significant main effects and two that did not meet the significance criteria. Specifically, the results show that by disregarding the frequency of instruction, participation of a cross-ability peer tutor in the classroom, or student gender, the main effect of achievement suggests that a significant difference in the mathematics achievement occurs between the pre-test and post-test scores , $F\ (1{,}199)\ =\ 938.06, p\ <\ .001$. For mathematical achievement, the effect size of $\eta = .91$ is considered to be much larger than typical. The main effect of frequency of instruction implies that, ignoring all other variables, those students who met twice per week scored significantly higher on the repeated measure than those who met only once per week $F\ (1{,}199)\ =\ 14.135, p\ <\ .001$. The effect size of $\eta = .26$ is considered a medium effect and accounts for 7% of the total variance. Conversely, neither the student's gender $F\ (1{,}199)\ =\ 2.893, p\ =\ .091$ nor the participation of a cross-ability peer tutor in the classroom $F\ (1{,}199)\ =\ .629, p\ <\ .429$, met the criteria for a significant main effect. Even though the data analysis does not

Table 10

Mixed Design ANOVA Source table for Frequency of Instruction, a Cross Ability Peer Tutor and Gender on Developmental Mathematics Achievement.

Source	Sum of Squares	*df*	Mean Square	*F*	*p*
Achievement	10480.968	1	10480.968	938.056	< .001
Gender	130.05	1	130.05	2.893	.091
Frequency	643.50	1	643.50	14.315	< .001
Tutor	28.26	1	28.26	.629	.429
Achievement x Gender	.129	1	.129	.012	.915
Achievement x Frequency	381.251	1	381.251	34.122	< .001
Achievement x Tutor	2.546	1	2.546	.228	.634
Gender x Frequency	12.29	1	12.29	.273	.602
Gender x Tutor	67.40	1	67.40	1.499	.222
Frequency x Tutor	23.170	1	23.170	.515	.474
Achievement x Gender x Frequency	3.114	1	3.114	.279	.598
Achievement x Gender x Tutor	4.977	1	4.977	.445	.505
Achievement x Frequency x Tutor	24.375	1	24.375	2.182	.141
Gender x Frequency x Tutor	55.25	1	55.25	1.229	.269
Achievement x Gender x Frequency x Tutor	28.346	1	28.346	2.537	.113

show significant main effects for gender and the cross-ability peer tutor, the small effect size of $\eta = .12$ is notable for gender but the effect size of $\eta = .05$ for the tutor would account for less than one quarter of one percent of the total variance.

To further control for type I familywise error rates, the use of the Bonferroni correction is applied to each of the significant effects. Computed by "dividing α by the by the number of comparisons, thus ensuring that the cumulative Type I error is below .05" (Field, 2009, p. 373), the Bonferroni correction does not alter the significance for any of the three significant effects of this study. Significance is still achieved for achievement, frequency of instruction and the achievement and frequency interaction, upon application of the Bonferroni adjustment.

The mathematical achievement and the frequency of instruction main effects are qualified by a single statistically significant interaction between mathematical achievement and frequency of instruction $F\ (1{,}199) = 34.122, p < .001$. This interaction, whose graphical representation is shown in Figure 2, has a medium to large effect size of $\eta = .38$. None of the remaining interactions between achievement and gender ($p = .915$), achievement and tutor ($p = .634$), frequency and tutor ($p = .474$), frequency and gender ($p = .602$), and tutor and gender ($p = .222$), result in significant interactions. Furthermore, none of the triple interactions result in significant interactions are all as is the quadruple interaction of achievement, frequency, tutor, and gender ($p = .113$).

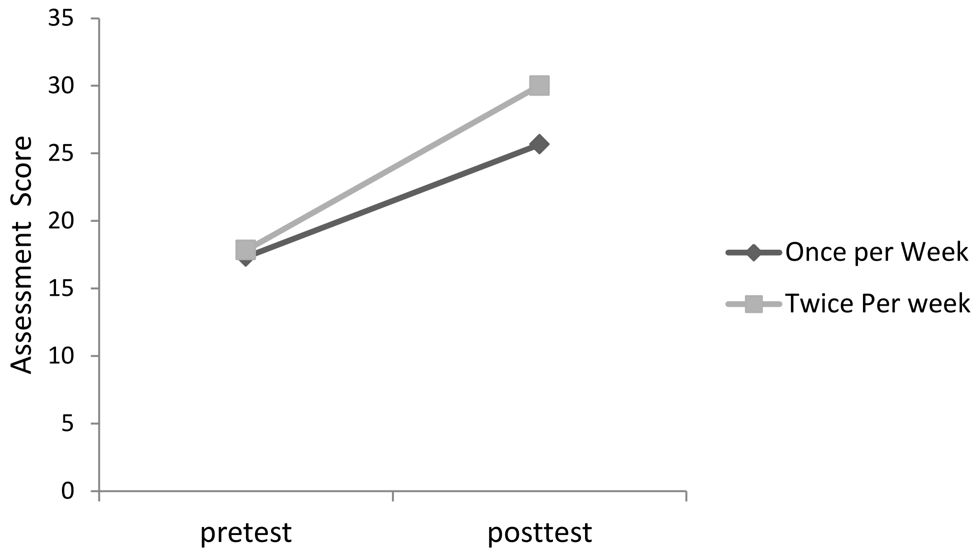

Figure 2. Graphical representation of the interaction between frequency of instruction and developmental mathematics achievement.

Summary of Quantitative Analysis

Quantitative analysis revealed that, regardless of gender or instructional method, a statistically significant difference in mathematical achievement occurs between the pre-test ($M = 17.61, SD = 5.593$) and post-test ($M = 28.09, SD = 5.424$). Furthermore, a significant difference in mathematical achievement occurs for those students whose frequency of instruction is twice per week as compared to those students who only meet once per week. Accordingly, a significant interaction between achievement and frequency of instruction follows. None of the other interactions reach a .05 level of significance.

Qualitative Analysis

The primary focus of the qualitative aspect of this study is to better understand the perceptions of the students, cross-ability peer tutor, and faculty member with regard to the interventions conducted on students enrolled in developmental mathematics classes at a private, not for profit University. Two variables, each applied to approximately half of the student classes result in four interventions. The variables include altering the frequency of instruction between once a week for two days and twice a week for one day and the assistance of a cross-ability peer tutor during class time. To accomplish this qualitative research, panel interviews were conducted with student groups for each of the four interventions and individual interviews were conducted with the cross-ability peer tutor and instructor to identify common influences surrounding the frequency of instruction and participation of a cross-ability peer tutor in the classroom. Qualitative data collected from interviews with the cross-ability peer tutor and faculty member supplements the student accounts of their perceptions of the developmental mathematics class.

Panel Interviews

Having completed their developmental mathematics class, five students of each gender and intervention strategy, thus totaling 40, were asked to participate in a panel interview. Twenty-two students agreed to participate in the panel interview. Four matched panel interviews were conducted, each involving only those students who were enrolled with similar intervention characteristics, frequency of instruction and participation of the cross-ability peer tutor in the classroom. The resulting sample, delineated by gender and tutor characteristic, is shown in Table 11.

Table 11
Sample Size of the four Student Interview Panels

	Once Per Week		Twice Per Week		
Cross Ability Peer Tutor	Male	Female	Male	Female	Total
Yes	2	3	3	3	11
No	3	3	2	3	11
Total	5	6	5	6	22

With the exception of question 3 which was only asked of those students enrolled in an intervention that included the cross-ability peer tutor in the classroom, each panel was asked the following set of questions, in the same order:

1. With respect to the basic mathematics class you have completed at this university, will you please describe your experience with your attendance for the class?
2. With respect to the basic mathematics class you have completed at this university, will you please describe your experience with your use of class time? What occurred during class?
3. With respect to the basic mathematics class you have completed at this university, will you please describe your experience with the tutor during class time?
4. With respect to the basic mathematics class you have completed at this university, will you please describe your experience with whether you thought the class was a good use of your time?

5. With respect to the basic mathematics class you have completed at this university, will you please describe your experience with your how often you worked on class material outside of class?
6. With respect to the basic mathematics class you have completed at this university, will you please describe your experience with the type of material you worked on outside of class?
7. With respect to the basic mathematics class you have completed at this university, will you please describe your experience with the tutor outside of class?
8. How would you describe your overall experience of the basic mathematics class you have completed at this university?
9. Would you like to discuss any other aspects of the basic mathematics class that you think impacted your learning?

Interview of Cross-Ability Peer Tutor

Following the student interviews, the cross-ability peer tutor was individually interviewed and responses transcribed adding yet more perspective to the emerging influences. The following list of questions was asked of the cross-ability peer tutor who tutored students during their scheduled class.

1. With respect to the basic mathematics course you tutored at the University, will you please describe your overall experience?
2. With respect to the basic mathematics class you tutored at the University, will you please describe your experience with tutoring students during class?

2.1. Did you observe any difference between students enrolled in a class that met once per week and those who met twice per week?

3. With respect to the basic mathematics class you tutored at the University, will you please describe your experience with tutoring students outside of class?
   3.1. Did you observe any difference between students enrolled in a class that met once per week and those who met twice per week?
4. With respect to the basic mathematics class you tutored at the University, will you please describe the type and/or quantity of questions students asked you?
   4.1. Did you observe any difference between students enrolled in a class that met once per week and those who met twice per week?
   4.2. Did you observe any difference in student willingness to ask for or accept help between those enrolled in a class that met once per week and those who met twice per week?
5. Would you like to discuss any other aspects of the class that you think impacted learning for those students enrolled in the developmental math class?

Interview of Faculty Member

Following the interview of the cross-ability peer tutor, the faculty member was interviewed and his responses were transcribed thus completing the qualitative data collection. The following list of questions was asked of the faculty member who taught the developmental mathematics course:

1. With respect to the basic mathematics course you teach at this University, will you please describe your overall experience?

2. With respect to the Basic Mathematics class you teach at this university, will you please describe your experience with the cross-ability peer tutor?
    2.1. Did you find the student helpful?
    2.2. Did you observe students interacting differently with the tutor than they do with you?
    2.3. Do you think similar effects would have occurred if the class size were simply halved?
    2.4. Will you request another cross-ability peer tutor from the Center for Academic Support?
3. With respect to the Basic Mathematics class you teach at this university, will you please describe your experience with student-faculty interactions during class
    3.1. Did you observe any interaction differences between those students enrolled in classes that met once per week and those who met twice per week?
4. With respect to the Basic Mathematics class you teach at this university, will you please describe your experience with student-faculty interactions outside of class?
    4.1. Did you observe any interaction differences between those students enrolled in classes that met once per week and those who met twice per week?
5. With respect to the Basic Mathematics class you teach at this university, will you please describe your experience with the type and/or quantity of questions students asked you.

5.1. Did you observe any difference in student willingness to ask for or accept help between students enrolled in classes that met once per week and those who met twice per week?

6. Would you like to discuss any other aspects of the class that you think impacted student learning?

Student, Faculty, and Cross-Ability Peer Tutor Responses

Verbal responses from all 24 student participants, the faculty member, and the cross-ability peer tutor were transcribed and analyzed to identify statements that described the student learning experience. Literal and implicit responses were examined, possible meanings were explored, and a detailed representation of student learning experiences in a developmental mathematics class developed. The organization of these experiences into a list of non-repetitive, non-overlapping statements yielded a list of 136 experiences. From these experiences, four external influences emerged; the class format and content, cross-ability peer tutor, faculty member, and learning experiences outside of class together form the extrinsic motivation necessary for students to be successful in their developmental mathematics class.

Perceptions of Class Format and Content

The instructional format for the basic mathematics course was a combination of direct and small group instruction. Meeting for a total of two hours per week, the class structure was delineated into five events including a review of past material often guided by homework questions, a small group formative assessment followed by an individual cumulative assessment, lecture, and another small group activity. For those students who meet twice per week for an hour each, the former three and latter two events occur on separate days.

The topics covered in the class include pre-algebra concepts including the development and solving of a single linear algebra equation. Students freely reported that the material covered in the class was “a review of math I should of [sic] learned before” or “stuff that I learned and forgot”. When one student remarked that “I learned it all in 5th grade” with obvious disdain for being required to take the class, another student quickly responded “you had to take the class too, so you obviously didn’t”. Every student brings with them past experiences and an attitude which together impact their motivation and ability to grasp the material.

The majority of students preferred working in small groups whereas a few completed the assignments alone even when given the opportunity to collaborate. The faculty member remarked that “I usually have two students per class who ask if it’s ok to work alone, which I always allow. They usually are students who are at opposite ends of the spectrum, one who needs a lot of help to understand the math and the other who just needs a quick review of the material”. Students had the ability to choose who, if anyone, they worked with on the collaborative activities although the instructor often quietly directed the tutor to specific students.

In vast contrast to the student experience for those who only met once per week, students enrolled in the developmental mathematics class with scheduled meetings twice per week expressed overwhelming approval when asked if the course was a good use of their time. Traditional academic courses at the university are regularly scheduled twice per week and the convenience of a basic mathematics course which meets only once per week is repeatedly noted as a positive attribute by students. Yet, students in the once per week class reported more difficulty with class attendance and completing the homework due to family and work commitments. The instructor corroborated the student reports, citing more absenteeism and less involvement from students who met once per week for two hours than those who met twice per week for one hour. In contrast, meeting twice per week was a non-issue for those students scheduled in that manner. Students neither reported its frequency as an inconvenience or detriment.

Cross-Ability Peer Tutor

Within a class for which the peer tutor was assigned, with the exception of cumulative assessments, the peer tutor could assist students anytime the student requested. Frequent breaks during class time allowed the tutor to move freely about the classroom to assist students. During times when the faculty member was teaching the class as a whole, the tutor often worked with a couple of students, quietly clarifying information as the faculty member presented it to the class. During times of small group activities, the cross-ability peer tutor walked amongst the students answering questions as he passed by.

Student perceptions surrounding the peer tutor were not in agreement. Remarking very little about the cross-ability peer tutor, many of the interviewed students did not utilize the tutor during class time and were simply accepting of him being there. Those students who did otherwise form an opinion of the interactions between the cross-ability peer tutor and students strongly voiced their position. Confirming the anomaly of responses, the tutor remarked that “I didn’t help many students during class but spent most of class with a couple of students”.

Not all of the student responses about the cross-ability peer tutor described positive interactions. Although a singularity, one student responded that the tutor was a disruptive influence to her learning and wanted "to be taught regular like [sic], you know, I just want the teacher to just teach me what I need to know for the tests". Alternatively, equally passionate, and with greater frequency were the responses describing the experience of students who routinely relied on the tutor during class time to answer questions, clarify or reiterate content.

Those students who discussed the tutor's influence reported that the cross-ability peer tutor provided a comfortable, collaborative, academic environment both in and outside the classroom. Students felt that they could ask the tutor questions that they would not ask the instructor for fear that they would sound "stupid" or that they might "be criticized". Working with students who were behind schedule, the tutor confirmed that student questions during class were often topics which had been covered previously or which students were expected to have known. Students reportedly appreciated this immediate feedback and stated that it helped them stay on task during class. "If I hadn't asked him [the cross-ability peer tutor] for help, I probably wouldn't have ever asked and would have been lost". The faculty member also commented that the tutor "was great for helping those students who normally would sponge most of my class time which then let me focus on the rest of students. Normally, I'd have to spend most of my time giving all my attention to those who are falling behind". Although the extent to which the tutor provided academic assistance for these students will never be known, the tutor clearly provided some positive academic support to several students in the developmental mathematics course.

Faculty Influence

Although the tutor certainly influenced some, students overwhelmingly agreed and repeatedly conveyed that the instructor was the primary reason for their success. The instructor created a comfortable, collaborative learning environment where students didn't feel "stupid". Although not explicitly requested, many students voluntarily began to discuss prior teachers who made students feel just that way. The perception that the instructor cared about each student's learning was an important characteristic across all of the panel interviews, but one which the instructor struggled with. "Remembering who they are was far more difficult when I only saw them once a week. I knew the names of students within a week when I saw them twice each week, but I had trouble all term remembering the names of those who attended only once".

Learning Experiences Outside of Class

Across the four different interventions and gender differences, students universally reported procrastinating assignments and putting forward little effort outside of class unless specifically required. Homework assignments were attempted immediately preceding its due date: "Since our class met in the afternoon, I usually did the homework or whatever the teacher asked us to do that morning before our class. That way I didn't forget before the quiz" Students with assignments due twice per week were therefore looking at material on two separate occasions whereas students whose class only met once per week were looking at the material only once during that same time frame.

Summary of Qualitative Analysis

Underlying the four aforementioned influences, students continually reported that the classroom experience provided the necessary motivation for them to complete their assignments, perform well on assessments, and understand the material. The class structure supported by a cross-ability peer tutor and quality faculty member provided a comfortable learning environment to ask questions and engage students. Greater rates of attendance were reported for students enrolled in classes which met twice per week. Correspondingly, students enrolled in a class scheduled to meet once per week reported higher difficulty with attendance and ability to complete assignments. The cross-ability peer tutor served a supportive role, motivating struggling students and allowing the faculty member to address the needs of the greater student body compared to just addressing the needs of a few. Outside of class students were motivated only by the assignment and its respective completion date. Challenged by a student's externalization of their intrinsic motivation the faculty member and cross-ability peer tutor remarked that they "can only do so much". There is little anyone can offer the student who obstructs the learning process, offering comments such as "I've always hated math", "I've never been any good at it and never will", and "why do I need to take it, I'll never use it", but perhaps the insight of Henry Ford: "Whether you believe you can or you can't, you are right" (Ford).

Summary

The quantitative findings reveal that regardless of instructional method, a significant difference between the pretest & posttest scores is evident. Furthermore, a significant difference in mathematical achievement exists between students who attend class twice per week for one hour and those who attend once per week for two hours. Discovery of the meaning and experience of students enrolled in the four interventions was challenging. Although the quantitative evidence did not support a difference in mathematical achievement of those who had a cross-ability peer tutor in the classroom and those students who did not, the qualitative evidence reveals that the limited number of students who interacted with the cross-ability peer tutor found the experience worthwhile. Equally, the general experience of all students involved was worthwhile. These experiences formed the necessary extrinsic motivation for students to be successful in their developmental mathematics class.

CHAPTER 5: DISCUSSION

The literature review revealed that many of the characteristics of remedial mathematics education have already been studied. It became evident, however, that two variables, frequency of instruction as well as cross-ability peer tutors in the developmental mathematics classroom have not been studied in-depth. The purpose of the study was to examine the possible differences between frequency of instruction, a cross-ability peer tutor, and gender on mathematical achievement of students enrolled in a developmental mathematics class at a private, not for profit, degree granting university then became obvious. This chapter briefly discusses the analysis, results, conclusions, correlations, implications, and suggestions for future research.

Determining an appropriate data analysis technique required consideration, reconsideration, and re-evaluation of the research questions to find questions and a technique which are both worthwhile and manageable for an emerging researcher. A mixed methods design was chosen which required both quantitative and qualitative analysis to analyze the overarching research question: What are the possible differences and meaning for frequency of instruction and involvement of a cross-ability peer tutor in the classroom on mathematical achievement in a developmental mathematics classroom? A 2x2x2x2 mixed ANOVA with repeated measures was chosen to analyze the quantitative data. Follow-up panel interviews with the students as well as individual interviews with the faculty member and cross-ability peer tutor provide the necessary insight into the meaning behind the quantitative data.

Expectedly, the results of the pretest and posttest, a repeated measure of mathematical achievement, show a significant difference, regardless of intervention. If no difference had been detected then one might conclude that the class itself had no effect on student mathematical achievement.

Frequency of Instruction

Results of this study suggest that the frequency of class meetings in conjunction with length of class time may impact student mathematical achievement. An increase in frequency, from once to twice per week and a decrease in class length, from two hours to one hour each was found to be a more effective method of instruction. This spacing effect amounts to more than a 10% increase between the pretest and posttest scores of students in each group; the mean score of students who met once per week is 64% compared to 75% for those students who met twice per week.

This result is supported by numerous studies in the field of psychology on the spacing effect, a well-documented effect on memory (Cepeda, Coburn, Rohrer, Wixted, Mozer, & Pashler, 2009). Researchers (Bahrick & Hall, 2005) hypothesize an explanation for the positive effects of spacing on learning; when study activities are spaced in time, students may notice that they have either forgotten or don't understand some of the material. A single class session may not afford the student enough time to realize which material is difficult to recall or understand. The instructor echoed those sentiments stating that students asked better questions and showed that they tried more problems in the class which met twice per week than those who only met once per week. Smith and Kimball (2010) also conjecture that, in addition to error correction, the spacing effect may also strengthen initially correct responses and increase confidence.

Cross-Ability Peer Tutor

The mixed results of this study with regard to a cross-ability peer tutor serving a supportive role during class instruction parallel the wide variations found in published findings. The quantitative results of this study do not suggest any benefit from having a cross-ability peer tutor in the classroom; the qualitative analysis, however, imply that the tutor markedly helped a limited number students succeed in the class.

Similar to Allsopp's (1997) study, this study reports that classwide peer tutoring is an effective instructional technique, but that it is no more effective than independent learning. Furthermore, Allsopp concludes that greater gain scores were achieved by those considered at risk of failure than those were not considered at risk for failure. Although not quantitatively analyzed by this study, the qualitative results support Allsopp's conclusions that a greater positive effect occurs for those students who engaged with the cross-ability peer tutor. Touting the benefits of the tutor, the instructor comments "Occasionally I asked the tutor to specifically assist a student who I could see was struggling or disengaged. He gave the necessary attention that I could not. I think that kept a few students in class who I thought were going to drop".

Research shows that faculty tend to spend the most time with students in need (Mercer, Nellis, Martinez, & Kirk, 2011). If the cross-ability peer tutor can assist the faculty member by helping the students most in need, the faculty member can then assist a far greater number of students. The hypothesis tested in this study, yet not supported by this study, was that the mathematics achievement of all students would benefit from the participation of a cross-ability peer tutor. It is supposed that this inconsistency may be caused by assuming that all students enrolled in the class would benefit from having the peer tutor in the classroom.

Gender

This study examined possible gender differences of students enrolled in a developmental mathematics class. Not surprisingly, a significant difference of gender on mathematics achievement was not supported. This sample of the general student population is quite specific; students enrolled in this developmental mathematics class are enrolled in a non-STEM degree program and have historically struggled with mathematics. Challenging the hypothesis that males, on average, demonstrate higher mathematical abilities than females, many researchers are relying on small effect sizes to support the gender similarities hypothesis with "most psychological gender differences are in the close-to zero $(d \leq 0.10)$ or small $(0.11 \leq d < 0.35)$ range" (Hyde, 2005, p. 581). The results of this study with a small effect size of $\eta = .12$ supports the gender similarities hypothesis of Scafidi & Khanh (2010), Else-Quest, Hyde, & Linn (2010), and Hyde (2005).

Implications

Recognizing that that the samples of students in this study are enrolled in non-STEM fields, it is hypothesized that the results of the frequency of instruction may be generalized to students enrolled in similar developmental mathematics programs. Administrators may choose to use the results of the spacing effect theory from this study this study to support or alter scheduling alternatives so as to increase the likelihood of student success. Faculty are often constrained by the predetermined schedules set forth by administration. However, faculty may similarly choose to reschedule assignment due dates, student-faculty appointments, or student-tutor appointments, so as to increase the frequency that students review class material.

Although inconclusive, the qualitative research supports the use of a cross-ability peer tutor in the classroom. Often, schools underutilize their student employees. If available, schools may choose to use qualified students as cross-ability peer tutors in appropriate classrooms.

Future Research

This study provides the groundwork for future research in the areas of spacing theory and tutoring for the developmental mathematics student at the postsecondary level. Because this study was only conducted at a single university, an attempt to replicate this study should be conducted before the results can be generalized.

It is important to note that the analysis of this study included only those students who completed the class; it is hypothesized that this data set inadequately addresses the effects of the cross-ability peer tutor on mathematical achievement. Future research should focus on the potential effects of the cross-ability peer tutor. Qualitative evidence suggests that some students would have dropped the course if it were not for the encouragement and engagement of the peer tutor “I never would have passed without his help”. More specific quantitative analysis of only those students engaged with the tutor, either during or outside of class hours, may produce a significant difference. In particular, one further study may be an investigation of the differences in the pass/fail rate of students enrolled in the class with the cross-ability peer and those without. Additionally, future research may focus on the mathematical achievement of those students who enter with significantly lower scores.

The demographics collected on students in this study only included gender. Future research may expand the attribute variables to include age, ethnicity, learning style, field of study, attitude toward mathematics, and time since previous mathematics class, to name a few. Similarly, the study was limited by the faculty member and tutor. Simply, one male instructor and one male cross-ability peer tutor were utilized for this study. Future research should include faculty and cross-ability peer tutors with varied teaching styles and attribute variables. This study could be expanded even further by varying the type of tutoring utilized in, and outside the classroom. A combination of the spacing effect with supplemental instruction could apply to classes constrained to meeting once per week; requiring students to engage in some type of supplemental instruction at regularly spaced and frequent intervals would prove to be an interesting study.

This study only considered two scheduling options; students were either scheduled once a week for two hours or twice a week for one hour, with the total number of hours per term remaining constant. Future research may include more variations of how the classes are spaced. One option may include meeting more frequently for a shorter period of time throughout the entire term or, alternatively, for a longer period of time and a shorter term length.

This study focused on developmental mathematics classes at a private university. Future research may expand the breadth of the study to include additional mathematics classes or varied subject areas. This study was limited to developmental mathematics at a University that does not offer degrees in mathematics. An expansion to include various types of postsecondary institutions could further support the generalization of this study.

Conclusion

Many students enter their postsecondary schooling without the necessary background in mathematics to be successful at the collegiate level. Developmental mathematics is currently a necessary aspect of postsecondary education. The importance of understanding the factors that contribute to student success in developmental mathematics is therefore critical for faculty and university administrators alike. The results of this study are but a small contribution to the ever-growing fields of developmental mathematics and tutoring research.

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APPENDIX 1: MATHEMATICAL ACHIEVEMENT ASSESSMENT,

PRETEST AND POSTTEST

1. Simplify: $3^2 - 6 \div 2$

a) 3 b) 6 c) $1\frac{1}{2}$ d) 1

---

2. Simplify: $25 + (12 - 10)^3 - \sqrt{16}$

a) 27 b) 26 c) 29 d) 17

---

3. Solve for x: $2x + 3 = 5$

a) 0 b) 1 c) 1/2 d) -1

---

4. Solve for x: $x - 2 + 2x = 4$

a) 0 b) 1 c) 2 d) -1

---

5. A candy wholesaler bundles 700 candies in a bulk bag. Your company needs to order 12,000 candies for a promotion. How many bags must you order?"

a) 17 b) 84 c) 18 d) 16

---

6. Solve for x: $x + \frac{2}{3} = \frac{5}{7}$

a) $\frac{3}{4}$ b) $\frac{7}{10}$ c) $\frac{1}{21}$ d) $1\frac{8}{21}$

---

7. Solve for x: $2x - \frac{3}{4}x = \frac{2}{3}$

a) $\frac{6}{8}$ b) $\frac{8}{15}$ c) $\frac{8}{33}$ d) $\frac{1}{9}$

---

8. What is ½ of ¾ ?

a) $\frac{2}{3}$ b) $\frac{4}{6}$ c) $\frac{3}{6}$ d) $\frac{3}{8}$

---

9. It takes 2/3 of a cup of brown sugar to make one batch of oatmeal cookies. How much sugar is required for 25 batches?

a) $16\frac{2}{3}$ cups b) 18 cups c) $\frac{54}{3}$ cups d) $23\frac{1}{3}$ cups

---

10. 5/6 of what number is 18?

a) $22\frac{1}{6}$ b) 15 c) 21 d) $21\frac{3}{5}$

---

11. The full tuition for an in-state resident is $22,750. A loan is acquired for 3/5 of the tuition. Ho w much is the loan for?

a) $13,650 b) $11,500 c) $ 12,250 d) $9,100

---

12. The full tuition for an in-state resident is $22,750. A loan is acquired for 3/5 of the tuition. Ho w much does the student currently owe?

a) $13,650 b) $11,500 c) $ 12,250 d) $9,100

---

13. Calculate the average of $10\frac{1}{2}, 2\frac{2}{3}$, and $\frac{3}{4}$

a) $13\frac{11}{12}$ b) $4\frac{23}{36}$ c) $4\frac{2}{3}$ d) 5

---

14. Solve for x: $\left(\frac{1}{3}\right)^2 + \frac{2}{3}x = 1$

a) 1 b) $\frac{4}{3}$ c) $1\frac{1}{3}$ d) 13.5

---

15. Solve for x: $2^3 + \frac{x}{2} = 10$

a) 36 b) 4 c) 1 d) 9

---

16. A 16-ounce bottle of dish soap costs $3.69. Find the unit price in cents per ounce. Round to the nearest cent.

a) 22¢/oz. b) 24¢/oz. c) 23¢/oz. d) 21¢/oz.

---

17. Solve for x: $0.2x + 7.5 = 10.7$

a) 1.0 b) 1.4 c) 1.45 d) 16

---

18. Solve for x: $5.2x - 1.3x = 12.48$

a) 1.0 b) 1.4 c) 1.92 d) 3.2

---

19. Simplify: $x + 2.5(.25x - 2)$

a) 1.625x + 5 b) 3.08 c) 1.625x - 5 d) -4.375

---

20. A loan of $25,650 is to be paid off in 36 monthly installments. How much is each payment?

a) $713.00 b) $712.50 c) $710.00 d) $2,137.50

---

21. Solve for *x*: $\frac{x}{4} = \frac{3}{8}$

a) $\frac{3}{32}$ b) $\frac{3}{2}$ c) $1\frac{1}{2}$ d) 4

---

22. Solve for *x*: $\frac{x+3}{4} = \frac{x-4}{8}$,

a) -10 b) $-\frac{7}{12}$ c) $1\frac{1}{2}$ d) 10

---

23. Solve for *x*: $\frac{133}{2.5} = \frac{x}{2}$

a) 120 b) 232.5 c) 106.4 d) 84

---

24. To determine the number of deer in a game reserve, a forest ranger catches 280 deer, tags them, and releases them. Later 405 deer are caught and it is found that 45 of them are tagged. Estimate how many deer are in the game preserve.

a) 2520 b) 6509 c) 12,600 d) 6850

---

25. If 3 sweatshirts cost a total of $125, what is the cost of 8 sweatshirts?

a) $333.36 b) $333.28 c) $201.50 d) $333.33

---

26. What is 24% of 80?

a) 19.2 b) 0.3 c) $33.3\overline{3}$ d) 20

---

27. What percent of 16 is 3?

a) $5.\overline{3}\%$ b) 18.75 % c) 48 % d) 4.8 %

---

28. 30% of what number is 6?

a) 1.8 b) 180 c) 20 d) 0.05

---

29. In a mathematics class of 34 students, 6 received an A grade. Find the percent of students in the mathematics class who received an A grade. Round to the nearest tenth of a percent.

a) 17% b) 0.2 c) 17.6% d) 17.65%

---

30. A fax machine originally marked at $285 is on sale for 18% off. What is the sales price?

a) $205.10 b) $79.80 c) $233.70 d) $51.30

---

31. What is the simple interest on a principal of $2,350 at the interest rate of 3.8% for 1 year?

a) $89.30 b) $195.05 c) $893.00 d) $2,439.30

---

32. If a restaurant sells 450 desserts in an evening, it is typical that 180 of them will be cheesecake. What percent of the desserts sold will be cheesecake?

a) 25 % b) 40 % c) 18 % d) 22 %

---

33. Gene's commission rate is 18 %. He receives a commission of $2,151 on the sale of stereo equipment. How much did he sell?

a) $28,555 b) $14,340 c) $38,718 d) $11,950

---

34. Which of the following is the largest?

a) 7% b) 2/3 c) $\frac{3}{5}$ d) $\frac{6}{7}$

---

35. The manager of a flower shop uses a markup rate of 40%. Find the price of a piece of pottery that cost the store $23.50.

a) $14.10 b) $9.40 c) $37.60 d) $32.90

---

36. Translate "the sum of three times a number and 4" into a mathematical expression

a) $x+12$ b) $3(x+4)$ c) $3+4x$ d)$4+3x$

---

37. Simplify: $6y-3(y-5)+8$

a) $3y+23$ b) $3y+7$ c) $9y+3$ d) $9y+23$

---

38. Solve for x: $7x-2(x+1)=-10+3x$

a) -5.5 b) -6 c) 2 d) -4

---

39. Simplify $\left(\frac{5}{9}\right)^2 \cdot \left(-\frac{6}{7}\right) \div \left(-\frac{2}{9}\right) \div (-5)$

a) $1\ \frac{2}{3}$ b) $-1\frac{2}{3}$ c) $2\frac{1}{5}$ d) $-\frac{5}{21}$

---

40. Frozen Yogurt is 88% water, by weight. How much yogurt is in a 4 oz. cone of frozen yogurt?

a) $2\ oz.$ b) $.88\ oz.$ c) $3.52\ oz.$ d) $.48\ oz$
