THE IMPACT OF KHAN ACADEMY MATH REMEDIATION ON NINTH GRADE STUDENT ACHIEVEMENT

by

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Liberty University

A Dissertation Presented in Partial Fulfillment Of the Requirements for the Degree Doctor of Education

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ABSTRACT

The purpose of this quasi-experimental study was to determine if using Khan Academy as math remediation for fifteen minutes per day during a ninth grade Math I class would significantly affect student math achievement as measured by the North Carolina READY Math I End-of-Course Assessment. This quantitative study conducted at two rural high schools in West Virginia used remediation theory to make a comparison against a control population with the independent variable being grade level instruction only or grade level instruction plus math remediation using Khan Academy. The participants in the study included 131 ninth grade high school students taking a Math I class in a traditional classroom setting between October 2016 and May of 2017. The researcher collected data from students’ pretest and posttest scores on the North Carolina READY Math I End-of-Course Assessment. The original intent was to use analysis of covariance (ANCOVA) to reduce the effects of any initial group differences. However, the data failed to pass the assumptions necessary for ANCOVA or t-test. So, a nonparametric test, Mann-Whitney U, was used in the analysis. There was no significant difference in the posttest scores of ninth grade Math I students receiving regular instruction only and those receiving regular instruction along with Khan Academy for math remediation. Suggestions for further research are included.

Keywords: mathematics, remediation, achievement, college-ready, career-ready, prerequisite, foundational
Dedication

After graduating with my master’s degree in May of 2008, I asked my mother if she thought I should one day pursue a doctoral degree. After all, I said I would most likely be 50 years old or even older before completing it. Her response was typical of such a wise person. She said, “Sandy, you’ll be 50 whether you get your doctorate or not, you might as well be 50 with a doctorate.” This work is dedicated to my precious mother, Betty Arbaugh, who went to be with the Lord November 5th, 2008. I love you Mom, and I’ll see you again one day.
Acknowledgments

First, I thank my God for being with me and guiding me throughout this endeavor. I was blessed with wonderful parents who valued education and always supported me. I thank my father, Earl Arbaugh, a teacher, who passed down the desire to educate another generation. I thank my mother, Betty Arbaugh, who always was and still is my greatest cheerleader. I thank my husband, David Simmons, for his patience and support through it all. I am so grateful for the two children that the Lord blessed me with. My son, Jacob, and my daughter, Jessie, are my inspiration and a driving force in this achievement. I am forever grateful for all of my family and friends who have supported me with their prayers and words of encouragement. Many thanks to my chair, Dr. Hunt, for reading, editing, and advising me along the way. Thanks also to Dr. Watson for his patience, guidance, and much assistance throughout the analysis of the data.
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List of Abbreviations

Analysis of Covariance (ANCOVA)

Common Core State Standards (CCSS)

Elementary and Secondary Education Act (ESEA)

National Assessment of Educational Progress (NAEP)

National Center for Education Statistics (NCES)

National Mathematics Advisory Panel (NMAP)

New England Board of Higher Education (NEBH)

North Carolina Department of Public Instruction (NCDPI)

Institutional Review Board (IRB)

Response to Intervention (RTI)

Standard Error of Measurement (SEM)

Statistical Package for the Social Sciences (SPSS)
CHAPTER ONE: INTRODUCTION

Background

In 2010, the blueprint for revising the Elementary and Secondary Education Act (ESEA) was released by the Obama Administration (U.S. Department of Education, 2011). The blueprint contains five key priorities with number one being college-and-career-ready students. The goal is that by the year 2020 every student in the U.S. will graduate from high school ready for college or a career. College readiness is defined as the ability to enter into and succeed at college level coursework without remediation (Achieve, 2015; Committee on Health Education, Labor, and Pensions, 2010; Maruyama, 2012). To reach this goal the Chief State School Officers and the National Governors Association developed Common Core State Standards (CCSS) in English and Mathematics (Committee on Health, Education, Labor, and Pensions, 2010, p. 2). Unfortunately, in 2011, the ACT reported that only 25% of high school graduates were college ready according to the benchmarks in Math, Science, English, and reading. The blueprint reported that half of new college students entering two-year institutions and four out of ten entering four-year institutions enroll in remedial courses (U.S. Department of Education, 2011). In fact, over one third of new college students enrolled in remedial or developmental classes in 2012 (Condition of Education, 2012). According to Bahr (2011), a large percentage of enrolling college students are placed in remedial coursework due to skill deficiencies in mathematics. The majority of these students who start college behind never attain college-level competency, and those that enter remediation at the lower end of the spectrum have the lowest graduation rates (Bahr, 2011).

Historically, societies that commanded mathematical skills flourished in all areas including health and medicine, finance and commerce, technology, exploration and navigation,
and forecasting. Sophisticated quantitative ability has been linked with the safety and well-being of a nation (U.S. Department of Education, 2008). During most of the 20th century, the U.S. was a leader in mathematical expertise, as evidenced by the number of specialists and the quality of science, engineering, and financial leadership programs (U.S. Department of Education, 2008). In 2008 the National Mathematics Advisory Panel (NMAP) predicted that the U.S. would lose its leadership status in the 21st century unless substantial and sustained changes occurred to the educational system (U.S. Department of Education, 2008). President Barack Obama echoed this view when he wrote, “America was once the best educated nation in the world” (U.S. Department of Education, 2011, p. 1). A recent survey conducted by Hart Research gave a scathing indictment of the U.S. education system’s ability to produce college-and-career-ready graduates (Achieve, 2015). The study showed that over the last ten years college instructor and employer perceptions of how public high schools are doing at preparing graduates for college and employment have declined. Seventy-eight percent of the college instructors surveyed think that public high schools are not doing a good job of preparing students to meet the expectations of college. Also, 62% of employers surveyed felt that public high schools were not doing a good job of preparing students for the workforce (Achieve, 2015). Eighty-eight percent of instructors at four-year colleges reported that students had gaps in their college preparation, and four out of five employers reported the same for the employment sector. Forty-nine percent of college students themselves reported that they had large gaps in one or more subject areas, and 83% reported having at least some gaps in one or more areas. Fifty-four percent of college instructors of two-year colleges and 44% of four-year college instructors reported that less than half of the high school graduates at their schools were adequately prepared in mathematics. Finally, 87% of college instructors were dissatisfied or very dissatisfied with how public high schools were doing
preparing students in the area of mathematics (Achieve, 2015).

According to NMAP, aside from economic leadership, the safety of the nation and the quality of life for individuals there are other reasons to be concerned about the mathematical ability of the nation (U.S. Department of Education, 2008). A well-educated and technical workforce is key to national leadership in a contemporary society. President Obama wrote that it was a moral imperative to provide a world-class education that secures “a more equal, fair, and just society” (U.S. Department of Education, 2011, p. 1). A sound mathematics education is of national importance not only for aspiring engineers and scientists but also for all of society (U.S. Department of Education, 2008). Individual citizens also benefit from a successful mathematics education. There is a significant correlation between high school mathematics through Algebra II and access to and graduation from college as well as employment earnings in the top quartile (U.S. Department of Education, 2008).

In 2011, using the average scores from the National Assessment of Educational Progress (NAEP), the National Center for Education Statistics (NCES) reported that 82% of fourth graders scored at or above Basic in mathematics (U.S. Department of Education, 2012). This percentage dropped to 73 for eighth graders and 64 for twelfth graders. Basic is defined as a partial mastery of the fundamental skills. Forty percent of fourth graders were reported at or above Proficient in mathematics. This drops to 35% for eighth graders and only 26% of twelfth graders scored at this level. Proficient is described as competent in challenging subject matter (U.S. Department of Education, 2012). Lastly, 7% of fourth graders were Advanced in mathematics. This dropped to just 3% for twelfth graders. Advanced is defined as demonstrating superior performance (U.S. Department of Education, 2012). While there were positive trends in mathematics for fourth and eighth graders, by the twelfth grade the percentages
in all three categories are still too low to be considered college-and-career-ready. This could be
due to the students’ first encounter with Algebra. The NMAP labels Algebra as a
These statistics are consistent with the growing, large-scale demand for remedial or
developmental mathematics courses in two- and four-year colleges across the nation.

Remedial or developmental education is not a 20th century phenomenon. According to
Boylan and White (1987), the need for remediation goes all the way back to 1636 with the
opening of Harvard College where Latin was the instructional language and was unfamiliar to
some of the religious clergy freshman. Initially, from the 1600s to the 1820s, students were
provided tutors and not offered remedial courses (Arendale, 2010). Then, later in 1849, the first
remedial program offering courses in reading, writing, and arithmetic was developed at
Wisconsin University. Eighty-eight percent of all their freshman students were enrolled in at
least one remedial course. The need for remedial education continued throughout the history of
post-secondary education and increased as fewer traditional students began to enroll in colleges
and universities. At the beginning of the 20th century American community colleges first
appeared in postsecondary education and brought with them more developmental or remedial
courses. In 1996 the NCES reported that 99% of U.S. public community colleges offered

Educational remediation is the reteaching and reinforcing of previously taught material
that was not mastered or retained. The purpose in the classroom is to level the playing field for
students who failed to master the prerequisite material necessary to be successful at their current
grade level (James & Folorunso, 2012). The process of remediation is based on the behaviorist
theory developed by B. F. Skinner. Behaviorism is based on learning strategies, feedback, or
reinforcement, and the resulting changes in behavior (Boylan & Saxon, 2015). A study by James and Folorunso (2012) that investigated the instructional strategies of feedback and remediation effects on secondary school students’ mathematic achievement was driven by the behaviorist theory. Their results showed that students receiving remediation with feedback outperformed students who only received feedback. The lowest performances came from the control group who received neither instructional strategy (James & Folorunso, 2012).

In a postsecondary remediation study by Barh (2008) similar findings were produced. College students who remediated successfully reached the goal of college-level mathematics achievement and had comparable outcomes to students who didn’t require remediation. The study concluded that postsecondary remedial mathematics programs can be used to resolve skill deficiencies if the student remediates successfully. It was found, however, that the majority of remedial students do not remediate successfully, and more research is needed to uncover what hinders their success (Barh, 2008). In a follow-up study Barh (2010) revisited the efficacy of postsecondary remediation by examining the depth and breadth of student deficiencies to see what effect, if any, these had on the success of the remediation. Barh (2010) concluded that regardless of the level of deficiency or the number of deficiencies, students who remediated successfully achieved mathematics and English competency and had similar levels of achievement overall. Thus, remediation was proven to be effective for students regardless of the severity or number of their learning deficits (Barh, 2010).

In a pilot study by Wenner, Burn, and Baer (2011), geoscience course students received mathematics remediation via supplemental online asynchronous learning modules. It was determined that student success was dependent upon their participation and completion of the modules and the successful remediation of the necessary quantitative skills. The study resulted
in at least modest gains in overall achievement with more significant gains achieved by students who completed all of the modules (Wenner, Burn, & Baer, 2011).

Research has shown remediation to be a valuable tool for leveling the field for students with deficiencies at both the secondary and postsecondary levels. To produce college-and-career-ready high school graduates and reduce the number of students enrolling in postsecondary remedial courses, remediation must begin earlier in a student’s education. Since the fourth and eighth grade scores reported by NCES were promising, but deficits appeared by twelfth grade, ninth grade is a logical starting point for the identification and remediation of deficits in mathematics (U.S. Department of Education, 2012). If a stand-alone remedial course for students having deficits is not an option, then remediation must occur within grade-level mathematics courses by ninth grade in order to fill in the gaps of student foundational math knowledge making it possible for them to learn algebraic concepts. Algebra is needed for all other mathematics courses in high school, and its prerequisites include a strong foundation in basic arithmetic (U.S. Department of Education, 2008; Brown & Quinn, 2007). Remediation of the basic arithmetic and pre-algebra skills would help ninth grade students strengthen their mathematical foundation (Barh, 2008; Barh, 2010; James & Folorunso, 2012). This would make reaching the goal of high school Algebra II a possibility for more students and in turn help them attend and graduate from college, thereby increasing their earning potential (U.S. Department of Education, 2008). A solution must be developed that allows for some remediation during regular, grade-level, high school mathematics courses (Harvey, 2013).

**Problem Statement**

In 2008, the NMAP’s Final Report recommended that curricular content should not revisit topics from prior years or previous mathematics courses. Instead, the curriculum should
progress through math topics emphasizing student proficiency at each level. Proficiency is described as an understanding of key concepts and competently executing standard algorithms with automaticity (U.S. Department of Education, 2008). The Obama Administration’s Blueprint for Reform (2011) called on all states to adopt state-developed standards in mathematics that produce college-and career-ready high school graduates. States were given the option of upgrading their own standards or adopting CCSS (U.S. Department of Education, 2011). In response to these recommendations, curricular changes have occurred across the nation resulting in a more rigorous curriculum that doesn’t allow for the review of prerequisite skills or the remediation of students who have gaps in their mathematical foundation. Research has shown that remediation works (Barh, 2008; Barh, 2010; James & Folorunso, 2012). Barh (2010) recommends that more research be done involving various approaches to remediation at the postsecondary level. Colleges and universities should not be alone in carrying the burden of making high school graduates college-and career-ready. According to Wimberly and Noeth (2005), preparation for college should begin in middle school. More remediation research is needed at the secondary level, and it must accommodate the curricular changes that have all but eliminated the review of previously-learned mathematical concepts. There is a need for cost-effective, alternative methods of math remediation for high school students that enable them to take college level mathematics courses (Harvey, 2013). Currently, interventions or remediation designed to improve college readiness in mathematics are promising, but limited (Hodara & Barton, 2014). While there are many studies of the effects of remediation at the postsecondary level there are not many at the high school level and none that included the use of online supplemental programs for math remediation used within a grade-level course. Most research at the middle and high school level involves after school and summer programs, stand-alone
remedial classes, or double dosing algebra courses for students needing remediation (Bushweller, 1998; James & Folorunso, 2012). There are some studies on the use of the online program, Khan Academy, as part of a regular grade-level curriculum that were successful in increasing student engagement and math achievement (Kronholz, 2012; Light & Pierson, 2014). While these studies were not specifically using Khan Academy as a remediation tool, the program itself was remediating some students in the studies due to its individualized instructional aspect.

More research is needed in the area of math remediation in high school grade level courses using online supplemental resources. A study using Khan Academy during regular ninth grade class meetings to remediate basic arithmetic and pre-algebra skills would fill a gap that exists in the current literature. Using a free, online supplemental resource like Khan Academy for math remediation would put students in charge of their own learning and increase student engagement (Light & Pierson, 2014). Also, if proven successful in raising math achievement, this type of remediation could be helpful throughout a student’s high school career using Khan Academy missions such as Geometry, Algebra II, Trigonometry, and on through Calculus. Missions in Khan Academy are units of study that include video lessons, practice problems, and short assessments (Khan Academy, 2015).

Purpose Statement

The purpose of this quasi-experimental study is to determine whether receiving fifteen minutes a day of mathematics remediation using Khan Academy during each regularly scheduled Math I class will significantly improve ninth grade students’ mathematics achievement as measured by the North Carolina READY Math I End-of-Course Assessment. It will make a comparison against a control population with the independent variable being grade level instruction only or grade level instruction plus math remediation using Khan Academy. The
dependent variable will be the North Carolina READY Math I End-of-Course Assessment scores at the conclusion of the study, and the pretest scores from that assessment will serve as the covariate for analysis.

**Significance of the Study**

This study will strengthen current research in several different areas in the field of educational research. While studies exist on the effects of math remediation at the secondary level (Bushweller, 1998; James & Folorunso, 2012) most involve standalone classes or summer programs. There are also several studies at the postsecondary level regarding math remediation (Attawell, Lavin, Domina, & Levey, 2006; Bahr, 2008; Bahr, 2010) and some that used online supplemental resources (Wenner, Burn, & Baer, 2011; López-Pérez, Pérez-López, Rodríguez-Arizá, & Argente-Linares, 2013). This study will help fill the gap in the literature that exists pertaining to mathematics remediation at the secondary level, the use of supplemental online resources for mathematics remediation, and remediation within a regularly scheduled math class. It will also provide more information on using Khan Academy in the classroom supplemental to regular instruction and explore its value as a mathematics remediation tool (Light & Pierson, 2014; Murphy, Gallagher, Krumm, Mislevy, & Hafter, 2014; Kronholz, 2012). This study is one of the first to use Khan Academy as a supplemental online resource for mathematics remediation during a ninth grade CCSS Math I class. This is important because it could provide high school teachers and school leaders with an option when looking for ways to remediate foundational mathematics skills during grade-level mathematics courses. This study does not seek to determine the best tool for mathematics remediation available but rather to review the effectiveness of one. This study seeks to determine the effectiveness of using Khan Academy as
a free, online math remediation tool in ninth grade classrooms to increase student mathematics achievement.

**Research Question**

**RQ1:** What is the effect of using Khan Academy as a supplemental online remediation tool on ninth grade students’ math achievement?

The null hypothesis for this study is:

**H₀₁:** There is no significant difference in the math achievement of ninth grade students who use Khan Academy as a supplemental remediation tool in addition to grade level instruction as opposed to ninth grade students who do not use Khan Academy as a remediation tool to supplement grade level instruction as measured by the North Carolina READY Math I End-of-Course Assessment.

**Definitions**


5. *Common Core State Standards* (CCSS) – academic standards in mathematics and English that outline what students should know and be able to do at the end of each grade (CCSS, 2015).

6. *Khan Academy* - free online program with video lessons, exercises, and quizzes in many different content areas (Khan Academy, 2015).

7. *North Carolina READY Math I End-of-Course Assessment* – a Math I, end of course test created by the State of North Carolina that is aligned with Common Core Standards. It is used to assess a student’s knowledge of Math I concepts as specified in the North Carolina Standard Course of Study.

8. *Smarter Balanced Consortium* – an agency located in California at UCLA’s Graduate School of Education & Information Studies that creates online assessments aligned with CCSS.
CHAPTER TWO: LITERATURE REVIEW

Overview

The purpose of this quantitative study is to determine whether receiving fifteen minutes a day of math remediation during a regularly scheduled grade-level Math I course will significantly improve ninth grade students’ mathematics achievement. Math I is a CCSS course that replaced the previously named Algebra I course in high schools residing in states that adopted Common Core. The remediation process involves the reviewing and relearning of the foundational skills that are prerequisite to learning algebra. The researcher reviewed literature related to remediation theory, algebra prerequisite skills, cognitive science, and the use of supplemental online resources to gain information and locate previous research on the effects of remediation on student achievement. While there is a plethora of research discussing developmental mathematics courses as well as college courses as stand-alone classes, a gap in the research exists concerning remediation that occurs concurrently with grade-level course work at the high school level. This review of the literature is divided into seven sections. The first section discusses the theoretical framework of remediation that guides the study and situates it within a larger context. The second section examines the basic foundational mathematics skills that are prerequisite to learning algebra. The third section highlights the cognitive science of mathematical learning including several current brain-based studies made possible by recent technological advances. The fourth section discusses the importance of prior knowledge in the acquisition of new information and academic achievement. The fifth section explores the use of supplemental online resources to increase student achievement, and the sixth section introduces Khan Academy as a math remediation tool. Finally, the last section summarizes the literature reviewed and how this study addresses the gaps in the current literature within the topic of math
remediation at the high school level.

**Remediation Theory**

Educational remediation involves reteaching and reinforcing previously taught material that was not mastered or retained. The purpose is to fill in the gaps of missed content usually because it is prerequisite to current grade level content. Remediation is grounded in the behaviorist theory developed by B. F. Skinner in 1938 in his first book, *The Behavior of Organisms* (Boylan & Saxon, 2015). The theory is based on learning strategies, feedback or reinforcement, and resulting changes in behavior. Skinner’s theory presents the idea that behavior is learned and reinforced by the environment using a schedule of reinforcement much like remediation. As with behaviorism, remediation assumes that the environment was at fault for the gaps in foundational knowledge and relies on reinforcement to increase student achievement. In math remediation, students watch as teachers model the steps for solving problems (stimulus), they practice mastering the techniques (response), and then the instructor reinforces their behavior (see Figure 1). Modeling, practicing, and providing corrective feedback are standard behaviorist practices. In educational remediation, student achievement is usually reinforced by the testing out of the remediation program once their performance meets the standard expectations (Boylan & Saxon, 2015).

Educational remediation, for many years, was viewed as a solution to a problem and was not researched or considered a topic worthy of study. It became a recognized field of study in the late 1960s when John Roueche, a researcher from the University of Texas in Austin, along with his colleagues, began studying existing remedial educational programs to discover what techniques were producing the best results. Much of their early research in the decade between 1968 and 1978 involved studying college level developmental mathematics courses that were
mostly watered-down versions of the regular college-level courses delivered by lecture (Roueche & Kirk, 1974). Their findings offered several recommendations for developing a successful remediation program at the college level. They supported the behaviorist techniques used at that time and reported them to be successful in remediating underprepared students. Roueche (1973) highlighted the importance of establishing clear goals and objectives for remediation, which was shown to help students be successful.

**Figure 1.** Behaviorism Remediation Flow Chart.

The concept of mastery learning was another aspect of successful remediation reported by Roueche and his colleagues (1973). Bloom’s (1968) theory of school learning and philosophy of mastery learning stated that given the correct conditions all students are capable of obtaining a high degree of learning. The philosophy supports that if students are given time, different opportunities to learn, and instruction that meets their current need and situation, 80% to 95% of students can achieve mastery in a given subject area. Based on this belief, in 1968
Bloom developed Learning for Mastery, a model for mastery learning that was practical for the classroom. According to the model, learning objectives are established from the instructional content and then what constitutes mastery is determined from those objectives. Assessments are used to ascertain if a student has attained mastery of the content (Bloom, 1968). The Learning for Mastery model requires the material to be broken down into smaller units with frequent formative tests or quizzes administered after each unit. Timely feedback of the results of each assessment is required for both the teacher and the students. This allows the teacher to determine which students have gained mastery and which ones have not (Bloom, 1968). Timely feedback like that provided by the Khan Academy’s “learning dashboard” also shows students where they have achieved mastery and where they still need more work (Murphy, et. al., 2014). In Bloom’s model, students who achieve mastery become peer tutors, and students who do not achieve mastery are given more instruction based on their needs and then retake the assessment. This process continues until virtually all of the students have achieved mastery (Bloom, 1968). Thus, mastery learning involves learning small units of instruction followed by frequent testing and timely feedback and requires the student to master each unit or objective before progressing to subsequent units. This provides regular reinforcement through the testing out of units and supports the development of prerequisite knowledge before progression (Roueche, 1968; Rouche & Wheeler, 1973).

By 1974, Roueche and Kirk were studying remediation using computer-assisted instruction which supported another one of their recommendations to accommodate different learners with individualized instruction and allowed students to learn at their own pace. As far back as 1968, a study by Kulik and Kulik found that using a computer as a tutor to supplement regular instruction positively affected students by improving attitudes, raising post-test scores,
and increasing the amount of learning in less time. Roueche and Roueche (1999) echoed these results in a study where computers were being used as math tutors in remedial college courses. Research in this area showed that computer-based instruction was most successful when it was supplemental to regular classroom activities and not the primary method of delivering instruction (Bonham, 1992).

Educational remediation theory as applied to this study suggests that the independent variable, Khan Academy, used as a supplemental online resource for mathematics remediation should positively influence the dependent variable, student math achievement. Students begin their personal journey with Khan Academy by choosing an avatar, and as they progress through their missions they can unlock other avatars as added motivation. Khan Academy uses points, badges, and avatars to motivate students, providing positive reinforcement for the fulfillment of mission requirements (Khan Academy, 2015). Khan Academy missions include smaller units or video lessons, practice problems, and short assessments. Students watch the videos, practice skills, and then take a quiz to assess whether or not they have mastered the skills. Immediate feedback is available for both the student and the teacher upon completion of the assessment. This aspect of Khan Academy supports Bloom’s (1968) model of mastery learning. This study proposes that using Khan Academy for math remediation just fifteen minutes per day during regular grade-level Math I courses will help ninth grade students fill in the gaps of their mathematical foundation, enabling them to learn the algebra content more efficiently and thereby significantly improve their math achievement.

**Foundational Math Skills**

The first step in designing a mathematics remediation program for ninth graders is to determine what foundational math skills are necessary for them to be successful in learning the
content of their grade level Math I course. According to the National Mathematics Advisory Panel (2008), mathematics achievement for students in the U.S. begins to decline in late middle school when algebra is first encountered. Algebra is a central concern and is seen as a gateway or sometimes a roadblock to later mathematics achievement. Research supports that successful completion of an Algebra II course in high school significantly correlates with success in college and earnings in the top quartile of employment income (U.S. Department of Education, 2008). Therefore, students must learn algebra in order to attain any higher form of mathematics and thereby increase their future earning potential. The National Mathematics Advisory Panel (NMAP) recommends that the National Assessment of Educational Progress (NAEP) and the individual state assessments emphasize the most critical concepts and prerequisite skills necessary for learning algebra. Interestingly, most of the basic skills necessary for learning algebra are taught during the elementary years sometime between the third and fifth grade (NMAP, 2008). The Panel (2008) recommends that students in grades PreK-8 attain both a conceptual understanding and a procedural fluency from the mathematics curriculum and be able to automatically recall basic facts. They define automatic as both quick and effortless as is the case with information that has been stored in long-term memory as opposed to relying on strategies. Fluency in the standard algorithms for addition, subtraction, multiplication, and division and an understanding of the commutative, associative, and distributive properties are seen as the most important. Lastly, fractions, decimals, and percents are another area of importance for the learning of algebra (NMAP, 2008).

In a peer-reviewed article on mathematics remediation, Kotsopoulos (2007) wrote that many high school students have difficulty recalling the basic multiplication tables, which severely limits their ability to learn algebra. She states that multiplication facts are unattainable
Robert Siegler from the Carnegie Mellon University, who coauthored 244 research titles regarding mathematical cognition, conducted a study that demonstrated the importance of early skills for students’ long-term mathematics achievement (Watts, Duncan, Siegler, & Davis-Kean, 2014). These researchers noted that high-quality mathematics instruction in elementary school was very important and that early interventions to improve students’ understanding in mathematics would improve their future achievement. The study also found that the mastery of basic skills like simple addition and subtraction in elementary school were strongly correlated to mathematical ability in high school. The study concluded that elementary school growth was a strong predictor of high school mathematics achievement (Watts, Duncan, Siegler, & Davis-Kean, 2014).

Some of the basic elementary level skills that have been deemed critical to success in high school algebra include addition, subtraction, multiplication, and division of all real numbers including the integers (negative numbers) and the rational numbers (fractions) along with the order of operations. Zientek, Schneider, and Onwuegbuzie (2014) also listed multiplication facts, fractions, and place value as foundational skills that should be acquired in elementary school but are lacking in many first-year college students. According to Brown and Quinn (2007), these basic math skills, especially fractions, have been well established as prerequisites for success in algebra. Fraction competency affects the transition from arithmetic to algebra-
most of algebra is built on a clear understanding of rational numbers (NMAP, 2008). This and many other basic math facts are absolutely necessary to be successful in any high school mathematics course.

According to Stigler, Givvin, and Thompson (2014) the nation is facing crises in community colleges because of high school students that are not prepared for college-level work. Due to the problems associated with poor basic mathematic skills, many students are being placed in remedial mathematics courses instead of college algebra. The fact is most students graduating from high school in the U.S. are not able to perform basic arithmetic, pre-algebra, or algebra even though most passed an algebra course in high school (Stigler, Givvin, & Thompson, 2014). Since math content builds on previously learned material, without early remediation, students who are lacking basic skills tend to fall further and further behind. These students may indeed graduate from high school but are not prepared for college mathematics.

Cognitive Science

Before there can be a solution to the problem of ill-prepared high school and college math students, there must be a better understanding of the cognitive functions that are involved in the learning of mathematics. Neuroscientific research has been studying the visual processing centers of the brain and how they relate to learning, particularly in mathematics and science. Eye-tracking technology has provided evidence of how visual information processing and working memory are inter-connected, and a link between working memory and eye-fixation data has been reported (Anderson, Love, & Tsai, 2014, p. 469). Eye-tracking technologies have also uncovered some of the effects of prior knowledge and how this influences the learner’s selective attention to text versus graphics during online learning. It has been discovered that students with prior knowledge of the subject matter transition more between text, graphics, and data diagrams.
than students without prior knowledge, suggesting a greater ability to integrate text and graphics.

In an eye-tracking study conducted on solving mathematical equations, the prior knowledge of students, their cognitive strategies, and the efficiency with which they solved the problems were revealed through their eye movements (Anderson, Love, & Tsai, 2014, p. 469). While manipulating the equations, the more knowledgeable students directed their attention more appropriately than students lacking prior knowledge (Anderson, Love, & Tsai, 2014, p. 470).

Researchers have also conducted studies on the correlation between brain measures and mathematical tasks to attempt to uncover how students experience math problems. One study of mathematics learning measured the cortical electrical activity during the task of translating between the symbolic and graphical representations of functions. Students who struggled more with the task showed the greatest brain activity, indicating a higher cognitive load than students who reported the task as easy (Anderson, Love, & Tsai, 2014, p. 471). A lack of prior knowledge and cognitive load are sources of some of the problems associated with learning capacity and working memory. Both eye-tracking and brain-based studies reveal a need for scaffolding strategies specifically designed to help alleviate the problems caused by cognitive load and a lack of prior knowledge in the learner (Anderson, Love, & Tsai, 2014, p. 472).

Research by Brush and Saye (2001) recommend scaffolding mathematical concepts through visual modeling while verbally explaining each step of the process and providing hints during student practice. According to Mayer and Moreno (2003) this type of scaffolding can reduce cognitive load. Khan Academy videos with narration provide the visual modeling and explanation necessary to scaffold multi-step mathematical problems. Hints are also available during the quizzes and the instructional videos can be viewed as often as needed. The use of online programs like Khan Academy can provide the individualized instruction necessary to
remediate students in their areas of weakness in a particular subject matter.

Menon (2014a) in *Arithmetic in the Child and Adult Brain* created a comprehensive handbook examining the brain and the cognitive processes that are involved in learning and doing arithmetic operations. He completed numerous studies that shed light on what parts of the brain are involved with the learning of new arithmetic facts and what parts are involved with working and long-term memory. The hippocampus and its circuitry make up the area of the brain that is directly involved with the development into adult like ways of processing. When children learn new math facts they gradually progress from problem solving like finger counting to memory retrieval. According to a recent study by Stanford University (Menon, 2014b) the memorization of multiplication tables, the alphabet, and other basic facts actually changes the landscape of a child’s brain. In children, as the hippocampus and prefrontal cortex of the brain process arithmetic facts it contributes to the more efficient, memory-based problem solving that is seen in adults. The hippocampus was found to be more active one year after memorizing certain math facts due to its role in shaping new memories. Since procedural strategies are more effortful than memory retrieval, problems that require procedural strategies activate more parts of the brain.

Studies have shown that an extensive network in the frontal and parietal cortices along with the basal ganglia are involved during procedural strategies (Grabner, Ansari, Koschutnig, Reishofer, Ebner, & Neuper, 2009). This phenomenon is negatively correlated with age, with younger children having more activations than adults. This is due to the fact that children are using strategies that require more effort as opposed to the fact retrieval processes of adults (Rivera, Reiss, Eckert, & Menon, 2005). At some point after basic arithmetic facts are initially learned and stored in the hippocampus, they are written to the well-developed information stores
of the neocortex or long-term memory (Menon, 214b). So, the hippocampus is the scaffold to
the neocortex, and this schema is built in a child's brain for future retrieval of information. If
something happens to short circuit the transfer or transition from the hippocampus to the
neocortex as in the case of a brain lesion, the information will not be written to long-term
memory and will only reside in working memory for a short time before it is replaced with other
information (Menon, 2014b). A study by Qin, et al., (2014) showed the hippocampal system as
pivotal to this transfer. Their study revealed that retrieval strategy use improved from childhood
through adolescence and into adulthood. They were able to detect this by decreased activation in
the hippocampus (Qin, et. al., 2014). Working memory has limited resources that must be shared
by all memory and processing tasks that are being held in working memory at any given time
(Oberauer & Kliegl, 2006). So, anything that can be written to long-term memory will help
alleviate the load on working memory and help with the complex problem solving involved in
mathematic calculations. How well children are able to make the shift from problem solving to
memory-retrieval is a predictor of their ultimate mathematics achievement. Students who do not
commit basic math facts and rules to memory do not form the brain connections needed for when
they get to algebra and beyond.

Menon’s study (2014a) found that addition and multiplication predominantly utilize
memory retrieval, while subtraction and division rely on strategies. This is because addition
algorithms and the multiplication tables are generally memorized while subtraction and division
require strategies for solving. He states that elementary school is the most important period for
the mastery of basic arithmetic facts, and over time a progression occurs from counting and other
effortful procedures to direct retrieval from memory (Menon, 2014a). Without this progression,
a student will forever have to rely on strategies or a calculator for basic arithmetic. This will
ultimately be too slow for higher-level mathematics and taxes working memory capacity that is needed for more complex problem solving. A plan of remediation supplementary to grade level mathematics courses over time could help students regain foundational arithmetic skills and thereby reduce in-class cognitive load and help them succeed in high school mathematics and beyond.

**Prior Knowledge**

Students who require remediation have a lack of prior knowledge in the given subject area or have a lack of knowledge in the prerequisite skills required for the given subject. Prior knowledge is what a learner already knows about a topic and according to Ausubel (1968) is the most important factor influencing learning. In a study conducted at the University of Granada by López-Pérez, Pérez-López, Rodríguez-Ariza, and Argente-Linares (2013) it was found that the degree of prior knowledge was a significant variable in determining student achievement. The study provided supplemental online resources to introductory level accounting students to be used on a voluntary basis. Student achievement was higher in students with prior knowledge of the subject matter. Also, students with poor prior knowledge of the subject were found more likely to use the voluntary online resources provided than those with prior knowledge. In a study by Yüksel (2014) that examined the impact of activity-based mathematics instruction on mathematics performance, and investigated the factors that contributed to mathematics performance, the researcher found that students with high prior knowledge and high self-regulation skills made greater gains in mathematics performance. The study discovered that students with high prior knowledge also had a more positive attitude toward mathematics, which leads to further success in the subject.

Seery and Donnelly (2012) found that the incorporation of new information by a novice
is more strongly influenced by their prior knowledge of a topic. This has to do with how well new information can be linked to some pre-existing knowledge in long-term memory. Thus, learners without prior knowledge use a significant amount of their limited working memory capacity accommodating new information, while learners with prior knowledge link the new information to existing knowledge. For learners with prior knowledge this decreases cognitive load on working or short-term memory. In the Seery and Donnelly (2012) study, ten pre-lecture online resources were developed addressing introductory chemistry topics. College students in their first year of chemistry were given access to the materials every week prior to lecture. The resources included a main objective, vocabulary, and a four-question quiz on the lecture material. At midterm, students with prior knowledge still outperformed students without prior knowledge by 6%. This was down from 19% on average over the previous six years. By the final exam the gap between students with and without prior knowledge in chemistry had closed completely. The online resources provided the remediation that the first-year university students without prior knowledge of chemistry needed to be successful in the course.

In mathematics, it is not only prior knowledge of the concept being studied, but also experience with various configurations of the problems that can influence student learning. A student has to read and understand both text and diagrams while making the connection with previously learned configurations. In a study of geometry problem solving by Lin and Lin (2014, p. 616), five problems involving similar triangles were presented to students with and without prior knowledge of the topic. Results of the study showed that prior knowledge of similar triangles was a significant predictor of the pass rate for a given problem. This was true for the first four problems that had simple configurations. However, the pass rate for the fifth problem was significantly lower for students with and without prior knowledge. This particular
problem required mentally rotating the triangles and identifying hidden elements. This showed that even students with prior knowledge of similar triangles still struggled with configuration comprehension (Lin & Lin, 2014). Pass rate on a problem with a complex configuration was dependent upon the prior knowledge of both the topic and the configuration of the triangles.

This is another way that prior knowledge affects the learning of new information in mathematics and is strongly influenced by and affects the ability to link new information with existing knowledge in long-term memory. Thus, a lack of prior knowledge in a concept and in the configuration of the problem increases cognitive load on the learner and can overload the limited capacity of the working memory (Seery & Donnelly, 2012).

Cognitive load describes the load occurring on human cognition when tasks are performed (Lin & Lin, 2014, p. 607). There are three components of cognitive load: intrinsic, extraneous, and germane. Intrinsic load is caused by the number and inter-relationship of elements being processed at the same time (Lin & Lin, 2014). Thus, intrinsic overload is caused by a lack of prior knowledge and the complexity of the material. Extraneous load can be caused by distractions such as unnecessary or irrelevant instructional design (Lin & Lin, 2014). Poor instructional materials that require too much working memory increase the extraneous load and decrease the learning capacity (Seery & Donnelly, 2012, p. 668). Lastly, germane load is the mental effort or load on the human cognitive system required for learning. Since working memory is limited, germane load is dependent on the prior knowledge of the learner that results in a lower intrinsic load on the cognitive system (Seery & Donnelly, 2012). Therefore, the intrinsic and extraneous loads can hinder learning while the germane load enables it (Lin & Lin, 2014). The goal of remediation in this study is to reduce intrinsic load caused by a lack of prior knowledge and limit extraneous load by choosing an online tool like Khan Academy that has a
relevant instructional design that is easy to use.

**Online Resources**

The use of supplemental online resources to reduce cognitive load and close the gap between students with and without prior knowledge has been well researched. Online supplemental resources have been used in a variety of ways with various educational strategies, interventions, and remediation to increase learning and deepen conceptual understanding in mathematics as well as other subjects. In math and science in particular there is a plethora of terminology and concepts that must be mastered in order to proceed to the next level of the curriculum. When these terms and concepts are missed or are not fully understood, it creates a weak foundation for the remaining courses in the subject matter. Students entering math and science courses without the necessary prerequisite knowledge are more likely to fail. Prior knowledge at the high school level has been shown to be a strong predictor of future performance at the college/university level (Seery & Donnelly, 2012, p. 668).

According to Butler, Marsh, Salvinsky & Baraniuk (2014, p. 332), cognitive science and technology can provide simple educational strategies that can be implemented to improve learning. Their study found that supplemental online resources providing problems for repeated practice, spacing, and timely feedback, and by requiring students to view the feedback and correct mistakes increased the learning and retention associated with weekly homework assignments. This simple and inexpensive intervention provided students with repeated practice spaced over time, allowing them to practice the retrieval of new information and correct any misconceptions early (Butler, Marsh, Salvinsky, & Baraniuk, 2014). Since the intervention was online it gave students access to the materials any time, allowing them to be in control of their own learning. Although the principles of cognitive science used in the study could have been
applied without the use of online resources, it is their belief that using technology to deliver the resources exponentially increased the effectiveness and impact of the principles. Technology provided a personalized learning experience that allowed each student to go at his or her own pace (Butler, Marsh, Salvinsky, & Baraniuk, 2014, p. 339).

Another study conducted by Vandewaetere and Clarebout (2013), showed that a learner-controlled online environment was associated with higher motivation and was determined not to increase extraneous cognitive load on the learner. When learners have full or partial control over the sequencing, pacing, or presentation of the learning environment, it is considered a learner-controlled (LC) environment. Learners are given the ability to define at least part of their own learning process tailored to their own interests, needs, and abilities. Students in the study reported less difficulty (higher germane load) and less mental effort (lower intrinsic load) than students who did not have control over their learning environment (Vandewaetere & Clarebout, 2013). The literature supports the use of computer-based learning environments such as online supplemental resources that complement traditional forms of instruction and give the learner partial control over the learning environment.

A case study conducted by Seery and Donnelly (2012) analyzed the impact of using supplemental online resources on those with and without prior knowledge in chemistry. Their study, mentioned earlier, created ten online prelecture resources introducing key concepts and included a quiz to be completed prior to the corresponding lecture. The resources allowed students to test their understanding and identify misconceptions caused by new terminology and concepts. This helped students without prior knowledge in chemistry by reducing cognitive load during lectures. The results of the case study revealed that the final exam scores for students with no prior knowledge in chemistry had improved significantly and that there was no longer a
stark difference in grades between students with and without prior knowledge of chemistry. The results of the study concluded that the use of online resources is an effective remediation method for increasing student-learning capacity in students lacking prior knowledge of the content (Seery & Donnelly, 2012).

In a blended learning environment, the Internet compliments traditional learning by providing access to tutorials, practice, review, and assessments with immediate feedback outside of the classroom. According to López-Pérez, Pérez-López, Rodríguez-Ariza, and Argente-Linares (2013) from a study at the University of Granada, the use of supplementary online activities can improve the learning process and contribute to an overall improvement in student achievement when they are used to understand the concepts and content of the subject. Online learning enables students to learn autonomously, gradually, and at their own pace. Their study combined face-to-face classroom learning with thirty supplementary online activities using the Moodle platform in an introductory accounting course. The online activities were voluntary and designed to reinforce the concepts and content presented in the classroom. The study found that the supplementary online activities did enhance the learning process and contributed to an improvement in students’ final grades especially for students lacking prior knowledge. Those students made greater use of the online resources and achieved positive effects from the online supplemental materials (López-Pérez, et al., 2013). The study showed that online supplemental resources could improve the learning process and contribute to an overall improvement in student achievement if they were designed appropriately. Online activities that provide some feedback with an explanation of why a response is wrong are particularly effective at building understanding of course content. Although this study involved accounting classes, this type of blended learning that provides immediate feedback and gives students the ability to correct
misconceptions is beneficial with any content. The study results encouraged teachers to try this approach to help students lacking prior knowledge and to improve learning outcomes and student achievement (López-Pérez, et al., 2013).

Pilot studies conducted by Wenner, Burn, and Baer (2011) revealed that online asynchronous learning modules effectively remediated students’ quantitative skills in introductory geoscience courses in community college and university settings. According to the authors, an increasing number of students are entering college underprepared in mathematics, creating a high demand for remedial mathematics courses. This is particularly disturbing since interest in STEM (science, technology, engineering, and mathematics) disciplines is influenced by student success in mathematics. When students enter college ill-equipped in the quantitative skills necessary for their introductory science courses and with a wide range of gaps in their foundational math skills, providing remediation can be very difficult. Various departments are given the task of “leveling the playing field” by addressing the students’ diverse quantitative remediation needs (Wenner, Burn, & Baer, 2011, p. 17). Given the wide range of mathematical skills needed in the various science courses it is impossible to create one remedial mathematics course that will meet all of their needs. Wenner, Burn, and Baer (2011), infused introductory geoscience courses with quantitative concepts via online tutorials. The online modules were assigned prior to each new quantitative concept being covered in the geoscience course. Pretests and posttests showed that the online modules increased students’ quantitative skills and survey responses indicated that students perceived that the modules helped them in the mathematics portion of the geoscience courses (Wenner, Burn, & Baer, 2011). When instructors introduced the modules, provided clear instructions for using the tutorials, and reinforced the use of them it resulted in higher levels of student completion. So, these instructional methods positively
influenced student motivation to use the modules and the post-module quizzes as tools for success in their geoscience course (Wenner, Burn, & Baer, 2011).

As early as 1986, studies by Kulik and Kulik (1991) using computer-based instruction to supplement regular instruction were found to be successful in employing the computer as a tutor. They reported more student learning in less time and higher post-test grades. In a later study of students with low prior knowledge, the researchers concluded that computer-based instruction raised student achievement. The study included computer-based instruction in several subjects including mathematics, science, reading and language, social studies, and vocational training, and the computers were used for tutoring, drill and practice, and programming (Kulik & Kulik, 1991). The idea of this study is to use an online program, Khan Academy, as a math tutor for ninth grade math students to remediate the prerequisite skills necessary for learning the grade-level Math I content and to see if the results of the previous studies will be duplicated in a high school setting during a regular, grade-level class environment.

**Khan Academy**

Khan Academy is a free, online program that offers thousands of video lessons, exercises, and quizzes in many different content areas. Its mission is to provide “a free world-class education for anyone, everywhere” (Khan Academy, 2015). The nonprofit education website was founded in 2006 and has about 3,500 math instructional videos available for viewing along with over 100,000 practice problems that offer instant feedback for students who can work at their own pace in or out of the classroom environment (Murphy, Gallagher, Krumm, Mislevy, & Hafter, 2014). It has become extremely popular, with users working over 700 million problems in 2013 alone. It started with math, science, and economics and now has expanded its offerings to include arts and humanities, computing, and test prep. Khan Academy is part of a new
In early 2010, Khan Academy had about 144,000 users per month and by February 2014 it had increased to around 10 million per month. These numbers indicate both the quality of Khan Academy and the increasing demand for individualized online instruction, particularly in mathematics. It was originally developed to offer one-on-one, online math tutoring to individual users outside of a classroom environment and is still predominantly used in this way (Murphy, et. al., 2014).

The Bill and Melinda Gates Foundation in September 2011 contracted SRI International to study the use of Khan Academy within the K-12 school environment. SRI International is a research institute that was established by Stanford University in 1946. SRI Education is the division of SRI that conducts research in the areas of educational technology, policy, and learning and development. During the two-year research study contracted through SRI International and conducted by Murphy, Gallagher, Krumm, Mislevy, and Hafter (2014), Khan Academy began working with schools to develop new and innovative ways of organizing and delivering instruction in the classroom. This step changed the Khan Academy experience for both students and their teachers.

The study included nine sites, twenty schools, and over seventy teachers during the 2011-2012 and the 2012-2013 school years. It explored how a group of California schools and Khan Academy collaborated to create and pilot several different methods of using Khan Academy in the classroom as a supplemental educational resource to enhance both teaching and learning (Murphy, et. al., 2014). All of the implementation methods used sought to accelerate, individualize, and deepen student learning. The study also examined how Khan Academy used the collaborative effort to make modifications to create a better product to meet both student and
educator needs in the K-12 environment. All of the participants in the study were volunteers, and five of the sites participated for one year while the other four sites participated in the study for both years (Murphy, et. al., 2014). The pilot study included charter, public, and independent schools at the elementary, middle, and high school levels. Its focus was on fifth to tenth grades with about 2000 participants in the study each year. Several of the sites were using Khan Academy for mathematics support with the majority of the sites serving low-income communities (Murphy, et. al., 2014). A large amount of data was collected including student and teacher surveys, administrator interviews, classroom observations, conversations, and interviews with teachers, students, and parents. Some standardized test scores and Khan Academy user data were also analyzed. The study focused on the implementation of Khan Academy in the classroom rather than the impact that it had on learning due to the wide variety of implementation methods across the various sites and the evolution of the Khan Academy resources over the time of the study (Murphy, et. al., 2014). All but one of the sites used Khan Academy to supplement the core curriculum rather than using it as the primary instruction method. Khan Academy used the study to gain insight on what changes needed to be made to their resources and refined and updated its tools as the study progressed (Murphy, et. al., 2014).

The nine sites included in the study used Khan Academy in a variety of ways and for different purposes. Some used it for additional practice utilizing the vast number of practice problems available, while other sites used Khan Academy specifically as an intervention for students who needed remediation. Others used Khan Academy for the advanced students as an enrichment tool, and many used it as an accountability tool to monitor student progress (Murphy, et. al., 2014). Khan Academy has been associated with the flipped classroom where teachers assign video lectures to be viewed at home while class time is used to discuss and work problems
(Parslow, 2012). However, this study involving nine separate sites, explored how Khan Academy could offer online individualized instruction within the classroom. Students in the study used Khan Academy primarily to practice problems, refine their skills, and work collaboratively with their peers (Murphy, et. al., 2014). With Khan Academy, students receive immediate feedback and are able to learn new math skills, hone their technology skills, remediate weak areas, monitor their own progress, and direct their own learning.

Two of the sites using Khan Academy in this study were selected to be included in this literature review because of their purpose for and implementation of Khan Academy. One of the sites was a high school in a high-poverty area where 75% of the students reported that English was not the primary language spoken in their home, and 80% qualified for free or reduced lunch (Murphy, et. al., 2014). The administrators and teachers at this site used Khan Academy to meet an urgent need for math remediation for their students. A significant number of their students entered ninth grade several grades behind academically. This made teaching and learning grade-level content extremely difficult if not impossible for these students (Murphy, et. al., 2014). There were two teachers involved with the study at this site, both of whom daily used Khan Academy in their classrooms. One teacher taught a ninth grade algebra readiness class and a learning lab. The other teacher taught an Algebra I class and a Geometry class, both with mixed ninth and tenth grade students, as well as a tenth grade Algebra II class (Murphy, et. al., 2014).

At this site, Khan Academy was used to support whole-class instruction directed by the teacher. Students worked within the same modules on the practice problems online in lieu of worksheets (Murphy, et. al., 2014). This facilitated the use of technology and provided the students and the teachers with instantaneous feedback. This site used Khan Academy to provide more structured practice sessions using hand-picked modules designed to remediate gaps in
students’ mathematical knowledge. The teachers also used Khan Academy modules to reinforce grade-level content that was being covered in the classroom (Murphy, et. al., 2014). Student progress and their time spent on the assignment were immediately available for both the student and the teacher. This was used to teach accountability to students and also provide teachers with information that helped them pinpoint problems that students were having mastering the content. Khan Academy feedback helped to draw a clear picture of the connection between effort and academic performance for the students (Murphy, et. al., 2014). The study also reported moderate to large differences in test scores following the addition of Khan Academy to the curriculum as compared with students who attended prior to the study. While the increase in test scores cannot be attributed solely to the addition of Khan Academy, it clearly played a role in student achievement at this test site (Murphy, et. al., 2014).

The second site from the study selected to be included in this literature review used Khan Academy to facilitate self-paced learning within their core curriculum. This site was a small school including grades 6-12 whose mission is to close the achievement gap for minority students and prepare their students for college. At the time of the study, 100% of the sites’ graduates had been accepted to 4-year colleges (Murphy, et. al., 2014b). The school has an extended day with mandatory afternoon sessions used for homework and tutoring. They used Khan Academy with their middle school grades by assigning videos and problem sets that were aligned with the math curriculum. The teachers created a “playlist” in Khan Academy and allowed the students to move through the modules at their own pace (Murphy, et. al., 2014b). They also assigned homework and paper quizzes that had to be passed in order to receive a passing grade. Many of the students were working on different modules and different assignments during the same class period because of the different levels and abilities of the
students. The teacher taught whole-class lessons twice a week, and the rest of the time was spent guiding and coaching students during their self-paced, student-directed Khan Academy missions (Murphy, et. al., 2014b). The whole-class lectures introduced new topics to the entire class while many students were working on different concepts within their Khan Academy missions. At this site, students were encouraged to collaborate with their peers while in Khan Academy and while doing homework assignments. When students were working in Khan Academy the teacher was able to spend time working individually with students who needed help (Murphy, et. al., 2014). It was easy for teachers to monitor students’ progress in Khan Academy. Teachers met with the students individually to discuss their progress and provide one-on-one tutoring.

At an elementary test site, achievement tests taken prior to and subsequent to the study were analyzed (Murphy, et. al., 2014). The test scores of the participants were divided into two groups: those scoring better than expected and those scoring lower than expected. The researchers discovered that fifth graders who surpassed expectations had spent an extra twelve hours using Khan Academy and had completed 39% more of the problem sets than their lower-performing peers. The sixth graders at this site who performed better than expected had spent an extra three hours and completed 22% more problem sets than their underperforming peers (Murphy, et. al., 2014). All of the students who reported having lower anxiety about math and more confidence in their ability to do math had completed 10% to 20% more problem sets than their peers. Although this study cannot make definitive claims about the efficacy of Khan Academy, the analysis does suggest correlations that are worthy of further study.

Most of the participating teachers were positive about their experience with Khan Academy. Eighty-nine percent of teachers across the sites reported that they would recommend it to others, and 86% planned to continue using it after the study concluded (Murphy, et. al.,
Eighty-five percent of the teachers stated that Khan Academy had a positive effect on student learning and especially student understanding of the material. They reported that the highest impact was on overall understanding of topics, ability to work and learn independently, and stronger procedural skills. Ninety-one percent of the teachers in the study also felt that Khan Academy increased their ability to provide practice of newly learned content (Murphy, et. al., 2014). Eight in ten of the teachers reported a greater ability to monitor student progress and identify both struggling and advanced students.

Some of the benefits of using Khan Academy for teaching and learning as reported by this two-year study are listed below (Murphy, et. al., 2014). First, student perception of Khan Academy was very positive, with 71% reporting that they enjoyed using it and 32% reporting that they liked math more after using Khan Academy. Student engagement was reportedly high during Khan Academy sessions as evidenced by classroom observations and teacher interviews. Also, 45% of students reported that they were able to learn on their own without the help of the teacher and were able to experience success when the problems became more challenging (Murphy, et. al., 2014). Student usage ranged from eleven to ninety minutes per week across the sites. While students were not required or expected to use Khan Academy outside of class, outside usage ranged from a few minutes to 25 minutes per week. Evidence resulting from the study indicated that students who spent the most time working in Khan Academy and those who successfully completed more problem sets experienced more positive outcomes in terms of test scores, more confidence in their ability, and less anxiety when doing math.

The participating teachers at the nine test sites offered their thoughts on the benefits of using Khan Academy in the classroom (Murphy, et. al., 2014). Teachers reported liking the modular nature of the videos coupled with the problems sets and how they could be assigned to
students separately and in no particular order, allowing students to focus on areas of weakness or skip ahead when they were ready to move on. This aspect of Khan Academy also allowed teachers to differentiate instruction within the classroom (Murphy, et. al., 2014). Teachers reported that the most valuable benefit of using Khan Academy was the rapid feedback without having to grade worksheets or homework to determine weak areas. Teachers also liked that Khan Academy gave students the ability to take charge of their own learning, which helped build their confidence in their ability to learn and work independently.

In response to this study, Khan Academy redesigned its website in July of 2013 releasing grade-level “missions” and a “learning dashboard” (Murphy, et. al., 2014). These changes were to help students focus on working in a particular content area suggested by their coach or selected on their own from their dashboard. While in a mission, the dashboard only shows content (videos and problem sets) related to that area of study. Khan Academy also created new videos and problem sets and aligned their existing videos and problem sets with the Common Core State Standards to help teachers find the appropriate content for their classroom (Murphy, et. al., 2014). To further ease the burden on teachers, Khan Academy sends student progress reports via email to the teacher/coach in the form of simplified, customizable summaries at both the class and individual student levels.

Overall, this study reported positive outcomes for teachers, educational leaders, and students, showing that schools with diverse student populations could adopt and implement Khan Academy in their math curriculum. Teachers in the pilot study reported that Khan Academy was a valuable tool to support instruction, that it helped students, and that they planned to continue using it in the future while experimenting with different methods of implementation (Murphy, et. al., 2014). Students also indicated that they liked Khan Academy, and student learning was
Kronholz (2012) wrote about two more of the schools in the previous pilot study that used Khan Academy to supplement classroom math lecture. In Los Altos, California, 115 students in fifth and seventh grade classes piloted Khan Academy and provided Khan feedback for refining the website and tools. The results were that 41% of the seventh grade remedial students who used Khan Academy scored proficient or advanced on their standardized tests compared to 23% the previous year. Ninety-six percent of the fifth graders in the pilot study were proficient or advanced compared to the rest of the district, 91%.

Envision Academy, a charter school located in downtown Oakland, also piloted Khan Academy in ninth grade algebra classes. Ruth Negash, the teacher at Envision, had used Khan Academy in a ninth-grade summer school algebra class and saw good results so she incorporated it into all of her ninth-grade algebra classes. At Envisions summer-school program, the Khan Academy class outscored the traditional algebra lecture class even though they only spent half of their time on algebra. The other half of their time was spent on improving lower-level mathematics skills while the traditional class spent all of its time on algebra (Kronholz, 2012).

Another Khan Academy pilot study supported by the J. A. and Kathryn Albertson Family Foundation took place in Idaho during the 2013-2014 school year. The study included 47 schools in 33 districts with 173 teachers and over 10,500 students. The pilot was designed to support innovation, learning, and flexibility for both teachers and students (Phillips & Cohen, 2015). The main focus of the study was to offer individualized learning for the students. Personalized learning is defined as tailoring learning to match each student’s weaknesses, strengths, and interests. This includes allowing students some control over their own learning
and supports the flexibility needed to help ensure mastery of the highest standards (Phillips & Cohen, 2015). Khan Academy offers a personalized learning platform with virtually a free tutor available to each student 24 hours a day, 7 days a week. Using Khan Academy in the classroom supports differentiated instruction by allowing students to work at their own pace and enabling teachers to offer more one-on-one help. Although it wasn’t the main purpose, the pilot study in Idaho did provide an analysis of the relationships between academic outcomes and Khan Academy usage (Phillips & Cohen, 2015).

Teachers were allowed to choose how they would use Khan Academy in their classrooms: as a tool to remediate, accelerate, supplement, teach, reteach, or as a primary instructional tool. Students in the study were required to use Khan Academy for at least one hour per week and were given the Northwest Evaluation Association’s (NWEA) Measures of Academic Progress (MAP) assessment three times during the study (Phillips & Cohen, 2015). Students were given the MAP assessment in the fall as a baseline, in the winter as a midpoint, and in the spring for the final assessment. Analysis from the study included data from 5,309 students in third through eighth grade that took both the fall and the spring MAP assessments. The analysis showed a positive correlation between academic progress and Khan Academy usage (Phillips & Cohen, 2015). A “target growth” was calculated for each student based on nationwide norms using their grade level and their fall percentile. Students completing 60% or more of their Khan Academy mission achieved 1.8 times their expected growth. Students completing 40% or more of their Khan Academy mission achieved 1.5 times their expected growth (Phillips & Cohen, 2015). Students who hardly used Khan Academy, completing 10% or less of their mission, grew as expected. The results of the analysis showed that students who completed more of their mission scored higher and showed more improvement than their peers.
The study cautioned the reader not to draw definitive conclusions due to the confounding factors including the various ways that Khan Academy was implemented across all the classrooms (Phillips & Cohen, 2015).

It is Khan Academy’s simple, straightforward approach that makes it a highly adaptable tool that is easy to integrate into any curriculum (Murphy, Gallagher, Krumm, Mislevy, & Hafter, 2014). Teachers can create classes in Khan Academy and have their students sign up, choosing them as their coach. They can also assign missions for their students to complete or allow the program to assign missions based on short assessments of individual student needs. At the beginning of every mission, the student is given a quiz with a short set of problems used to assess their prerequisite skill level. Then the student can watch video lessons, work through sample problems, and take quizzes. Their mission is completed only after the student has mastered all of the skills of that mission (Khan Academy, 2015). This type of mastery learning is often referred to as math fluency and requires students to stay at a particular level until mastery is reached. The implementation of mastery learning in a whole classroom is time consuming and usually doesn’t allow teachers to move through the required standards quickly enough.

Math fluency development was the focus of a study by Poncy, Skinner, and Axtell (2010) that targeted struggling students for mathematics remediation. With the use of Khan Academy, students can receive the individualized instruction that allows for math fluency at the student’s pace without slowing down the pace of the classroom. According to a study by Light and Pierson (2014), the Khan Academy digital learning environment increased student engagement and changed the way that students engaged with the math content. Recently, the New England Board of Higher Education (NEBH) received a grant from the Lumina Foundation for Education
to support community colleges implementing Khan Academy materials in developmental mathematics courses.

Educational leaders are drawn to Khan Academy because it is free to everyone, engages students, gives instantaneous feedback, has modular resources, and facilitates student-directed learning. The educational community can benefit from further research of detailed use cases that describe how Khan Academy can be used in different environments under different instructional goals and the possible impact on student math achievement (Murphy, et. al., 2014). For the purpose of this study, Khan Academy will be used as a mathematics remediation tool to reteach foundational math concepts to students to support their success in their current grade-level Math I class as well as subsequent classes.

**Discussion and Conclusion**

In this study, remediation theory supports that the independent variable, Khan Academy, used as a supplemental online resource for the purpose of remediation, should positively affect the dependent variable, student mathematics achievement. The researcher proposes that Khan Academy will help students fill in the gaps of their foundational mathematics knowledge base by reteaching and reinforcing the prerequisite skills necessary for algebra and subsequent mathematics courses. A review of the literature discussed Skinner’s behaviorist theory as the foundation of remediation theory. As with remediation, behaviorism assumes that the environment is at fault for foundational knowledge gaps and uses a schedule of reinforcement to increase student achievement (Boylan & Saxon, 2015). The researcher also introduced the basic arithmetic skills necessary for learning algebra. These include addition, subtraction, multiplication, and division of all real numbers including integers and especially fractions (NMAP, 2008). The review also included a discussion of the cognitive science of mathematical
learning and the significant role of prior knowledge in academic achievement and its association with cognitive load on working memory. The use of eye-tracking technologies discovered that students with prior knowledge transitioned more between graphics, texts, and diagrams than students without prior knowledge, signifying a greater ability to integrate text and graphics. In a study conducted by Anderson, Love, and Tsai (2014), the students with prior knowledge of the subject directed their attention more appropriately than students lacking prior knowledge. A study that measured the cortical electrical activity of the brain during operations on functions also showed that struggling students had the greatest brain activity indicating a higher cognitive load than students who reported the task as easy (Anderson, Love, & Tsai, 2014). The researcher explored the use of supplemental online resources to increase academic achievement as well as introducing Khan Academy as an online mathematics remediation tool. Online supplemental resources provide repeated practice spaced over time with immediate feedback, allowing students some control of their own learning (Butler, Marsh, Salvinsky, & Baraniuk, 2014). When students enter college with weak quantitative skills it affects their ability to succeed in other coursework such as science and business. The task of addressing the diverse remediation needs of the various students affects multiple departments (Wenner, Burn, & Baer, 2011). The use of online resources like Khan Academy can provide remediation tailored for the individual student available outside of the classroom.

The need for remediating basic arithmetic skills at the high school level must be met with research-driven programs that will prepare students to be college or career ready at graduation. Many of the existing programs are expensive and hard to implement. Much of the research in this area focuses on afterschool programs, tutoring, and stand-alone remedial courses. This study will investigate a supplemental program of remediation that can occur during regular class time
and specific to mathematics. Using a free online resource like Khan Academy for short periods of time during regular class meetings to supplement grade-level mathematics courses may be a solution. If successful, this type of remediation could become self-regulating and continue throughout a student’s high school and college career.
CHAPTER THREE: METHODS

Design

A quasi-experimental nonequivalent control group research design was intended for this study because the random assignment of research participants was not feasible (Gall, Gall, & Borg, 2003). A static-group comparison was used, however, because the data failed to pass the assumptions necessary for ANCOVA. Intact ninth grade student groups in established classrooms were used as treatment or control groups. A pretest and posttest were given to all of the ninth-grade students. The dependent variable, mathematics achievement, was measured by the posttest and the pretest was to be used as a covariate. The control, grade level instruction, and the treatment, grade level instruction plus Khan Academy math remediation, served as the independent variable. The treatment group used Khan Academy for a minimum of fifteen minutes at the beginning of every class meeting as a ‘warm up’ or ‘bell ringer’ activity to remediate basic math skills. The control group engaged in ‘bell ringer’ activities that varied from teacher to teacher and were not necessarily aimed at remediating pre-algebra skills.

Research Question

**RQ1:** What is the effect of using Khan Academy as a supplemental online remediation tool on ninth grade students’ mathematics achievement?

The null hypothesis for this study is:

**H\(_0\):** There is no significant difference in the math achievement of ninth grade students who use Khan Academy as a supplemental remediation tool in addition to grade level instruction as opposed to ninth grade students who do not use Khan Academy as a remediation tool to supplement grade level instruction as measured by the North Carolina READY Math I End-of-Course Assessment.
Participants and Setting

The participants for the study include a convenience sample of ninth grade students from two rural southern West Virginia high schools (A and B) during the fall and spring semesters of the 2016-2017 school year. According to Public School Review (2016), for the 2013-2014 school year, high school A had approximately 660 students in grades 9-12. The student to teacher ratio is 14:1, which is lower than the state average of 15:1. Minority enrollment is 2% of the student body (majority African-American), which is lower than the state average of 9%. Fifty-four percent of the student body is male, and 46% is female. Fifty-two percent of students are eligible for free or reduced lunch, which is twice the state average of 26%. High school B for the same year, according to Public School Review (2016), had approximately 560 students in grades 9-12. The student to teacher ratio is 13:1, and minority enrollment is 3% of the student body (majority African-American). The student body is 50% male and 50% female, and 48% of students are eligible for free or reduced lunch. While the results of this study are not transferable to all ninth-grade students in the United States, it is a representative sample of the population of ninth graders attending rural high schools in the state of West Virginia.

The study consisted of 131 students enrolled in twelve ninth grade Math I classes taught by five different teachers from two different high schools. The treatment group consisted of six different Math I classes with a total of 74 students. There were also 57 students from six different Math I classes in the control group. The sample exceeded the 15 participants for each group being compared in an experimental research study as recommended by Gall, Gall, and Borg (2003). The average age of the participants was 14. All of the Math I classes used the same pacing guides developed by the county board of education and the same curriculum as outlined by the state of West Virginia Common Core standard objectives. Both the control and the experimental groups included two special education inclusion classes and four regular education
classes.

**Instrumentation**

The pretest and posttest scores from the North Carolina READY Math I End-of-Course Assessment were used to determine the achievement levels in mathematics.

**Reliability**

The North Carolina READY Math I End-of-Course Assessment was administered operationally for the first time in North Carolina during the 2012-2013 school year. This test was chosen for this study because it is aligned to Common Core, and it meets or exceeds the industry norm for reliability. At the time of this study, the State of West Virginia’s end of course assessment for Math I had just been released and did not meet the reliability criteria needed to use it as an instrument for the study. The measures of internal consistency as calculated by Cronbach’s alpha for the Math I assessment were .90 and .91 depending on which test form (A, B, M, or N) was given (Reliability, 2014). Table 3.1 shows the North Carolina READY Math I End-of-Course Assessment reliabilities.

Table 3.1

*EOC Math I Reliabilities (Edition 2)*

<table>
<thead>
<tr>
<th></th>
<th>Form</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EOC</td>
<td>A</td>
<td>B</td>
<td>M</td>
<td>N</td>
</tr>
<tr>
<td>Math I</td>
<td>0.91</td>
<td>0.91</td>
<td>0.9</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Validity**

Table 3.2 presents the validity evidence for the Math I end-of-grade and end-of-course assessments provided by the North Carolina Department of Public Instruction (NCDPI) (The

http://www.ncpublicschools.org/docs/accountability/testing/technotes/mathtechreport1215.pdf.

Table 3.2

*NCDPI Validation Framework for Math EOG and EOC Assessments*

<table>
<thead>
<tr>
<th>Basis for Validity Evidence</th>
<th>Data</th>
<th>Technical Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intended uses</td>
<td>Score Reports</td>
<td>Chapters 2, 9</td>
</tr>
<tr>
<td>Content</td>
<td>SEC alignment part 1</td>
<td>Chapter 10</td>
</tr>
<tr>
<td>Careful test construction</td>
<td>Test construction steps, item review map</td>
<td>Chapter 3</td>
</tr>
<tr>
<td>Appropriate test administration</td>
<td></td>
<td>Chapter 5</td>
</tr>
<tr>
<td>Internal structure and reliability</td>
<td>Cronbach’s alpha and SEM, classification</td>
<td>Chapter 10</td>
</tr>
<tr>
<td></td>
<td>consistency, Principal Component Analysis</td>
<td></td>
</tr>
<tr>
<td>Appropriate scoring and standard setting</td>
<td>Standard Setting Report</td>
<td>Chapters 7, 8</td>
</tr>
<tr>
<td>Careful attention to fairness for all test takers</td>
<td>Test Accommodation</td>
<td>Chapters 5, 10</td>
</tr>
<tr>
<td>Appropriate reporting</td>
<td></td>
<td>Chapter 9</td>
</tr>
<tr>
<td>Relations to other variables</td>
<td>Quartile Framework Linking study</td>
<td>Chapter 10</td>
</tr>
</tbody>
</table>

Table 3.2 reveals some of the processes that the NCDPI went through to determine that
the content of the North Carolina READY Math I End-of-Course Assessment was a valid Math I assessment as it aligns with Common Core. Although the intended use of the assessment for this study has changed from its original intent as an end-of-course assessment, it is still being used to assess the level at which a student has mastered Common Core Math I content. This retired test version is currently being used in Math I courses as a benchmark or practice test to prepare students for their actual end-of-course assessment. For the purposes of this study, the researcher mapped the North Carolina CCSS’s as they applied to the assessment items (see Appendix F) to the West Virginia CCSS’s (see Appendix E). Some of the items on the assessment did not immediately align with the West Virginia CCSS’s (see Appendix G). Upon further examination of the individual items, the researcher determined that most of them do fall under the West Virginia CCSS’s or are currently being taught by the ninth-grade math teachers participating in the study as indicated by the 2016 Math I pacing guide developed by the school district (see Appendix H). Table 3.3 gives an explanation of each of these items from the assessment. The last two items from the table, 9 and 16, on the assessment are not normally taught in the Math I classes involved in the study. However, any student who finishes the assigned Khan Academy missions, “Arithmetic” and “Pre-Algebra” and goes on to the “Algebra Basics” mission prior to the end of the study would have an opportunity to cover the concepts in items 9 and 16 on the test.
Table 3.3

Unmapped Test Items

<table>
<thead>
<tr>
<th>NC Standard</th>
<th>Item</th>
<th>Topic</th>
<th>Skills Required</th>
<th>WV Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.APR.A.1</td>
<td>33</td>
<td>The area of a trapezoid given the height as a constant and the bases as binomials</td>
<td>add binomials, combine like terms, distributive property</td>
<td>M.2HS.ENS.6 uses M.1HS.RBQ.5</td>
</tr>
<tr>
<td>A.SSE.A.2</td>
<td>3</td>
<td>Factor a quadratic</td>
<td>factoring - the difference of squares</td>
<td>M.2HS.EE.2 FOIL and factoring trinomials (a = 1) - taught in Math I</td>
</tr>
<tr>
<td>F.IF.C.8.A</td>
<td>13</td>
<td>The hypotenuse and one leg of a right triangle are described as longer than the other leg.</td>
<td>Pythagorean Theorem, FOIL, combine like terms, factoring a trinomial</td>
<td>M.2HS.QFM.5a uses M.1HS.RBQ.5</td>
</tr>
<tr>
<td>F.IF.C.8.B</td>
<td>38</td>
<td>Exponential function</td>
<td>Exponential function</td>
<td>M.2HS.QFM.5b uses M.1HS.RBQ.4b or M.1HS.LER.9</td>
</tr>
<tr>
<td>G.GMD.A.3</td>
<td>46</td>
<td>Given the volume of a sphere and the formula solve for the diameter.</td>
<td>solve for a variable in a formula</td>
<td>M.2HS.C.10 uses M.1HS.RBQ.8</td>
</tr>
<tr>
<td>G.GPE.B.6</td>
<td>44</td>
<td>Given a line segment with points use the midpoint formula twice</td>
<td>Midpoint formula, solve for a variable in a formula</td>
<td>M.2HS.STP.9 taught with the distance formula uses M.1HS.CAG.3 or M.1HS.RBQ.8</td>
</tr>
<tr>
<td>N.RN.A.2</td>
<td>20</td>
<td>Use the rules of exponents</td>
<td>raise a power to a power</td>
<td>M.2HS.ENS.2 taught prior to FOIL in Math I</td>
</tr>
<tr>
<td>N.RN.A.2</td>
<td>16</td>
<td>Simplify a cube root and rewrite it with rational exponents</td>
<td>take the cube root of a constant, rewrite a radical as a rational exponent</td>
<td>M.2HS.ENS.2 not taught in Math I</td>
</tr>
<tr>
<td>F.IF.C.8.A</td>
<td>9</td>
<td>Solve a quadratic equation</td>
<td>find the zeros of a quadratic equation</td>
<td>M.2HS.QFM.5a not taught in Math I</td>
</tr>
</tbody>
</table>
Procedures

Prior to conducting the study, the researcher was given permission by the North Carolina Public Schools to use the North Carolina READY Math I End-of-Course Assessment (see Appendix D) as the instrument for the study. The researcher also obtained permission from the county board of education and the school administrations to use the two high schools, the teachers, and the students for the study (see Appendix A). Approval was also secured from the Institutional Review Board (IRB) of Liberty University. Once these approvals were granted, ninth grade teachers at both of the high schools were introduced to the study (see Appendix B).

After all approvals and permissions were secured and teacher participation was determined, the participating teachers attended a short Khan Academy presentation (see Appendix C) and were briefed on the procedures that the researcher would be following. The control and experimental groups were determined, and the researcher then created a class with the Arithmetic mission and a class with the Pre-Algebra mission for each Math I class in the experimental group. The researcher also created a class with the Algebra Basics mission for each Math I class in the experimental group for students who finished both missions and were waiting to take the posttest. The study was scheduled to begin in October of 2016, as soon as all ninth-grade students in the experimental groups had received their iPad issued by the county and had their email accounts set up. All participating teachers with either an experimental group or a control group were asked to administer a paper-and-pencil pretest, the North Carolina READY Math I End-of-Course Assessment, to their students on a specified date. All participating teachers with an experimental group then showed their class two Khan Academy videos (see Appendix I). The first video is a motivational video introducing the students to Khan Academy. The second video is an instructional video that illustrates the Khan Academy student experience. The teachers informed their students that an invitation would be coming to their student email
account and that they would be creating their user accounts and starting their first mission together on a specified date. Students were asked to be sure to bring their iPad fully charged on that date and to make sure that they had access to their school email account.

On the specified date the researcher went to each Math I class in the experimental group at high school A and instructed the students to open the email that was sent to them and click on the Khan Academy link. They were then instructed to fill out the username and password screen using their first and last initials plus the last five digits of their student identification number and a memorable password. They were then asked to write down their username and password on a piece of paper and turn it in to their teacher. The researcher typed up a list of the usernames and passwords and gave it to the classroom teacher to keep in case a student forgot their password. The researcher then visited high school B and went through the same set up procedures with those students in the experimental group.

The first fifteen minutes of class is used by teachers for a ‘warm up’ or ‘bell ringer’ assignment that is completed during announcements and while the teacher is taking attendance. The ‘warm up’ activity is required by administration and is included in the administration’s walk-through checklist used for informal teacher evaluations. The students in the treatment groups used Khan Academy as their required classroom ‘warm up’ activity during the first fifteen minutes of class every day until all of the students in the experimental groups had completed the two required Khan Academy missions, Arithmetic and Pre-Algebra. The control groups followed their regular routine and as part of the normal process were given ‘warm up’ assignments that varied from teacher to teacher. The assignments were not necessarily aimed at remediating basic arithmetic and pre-algebra skills but included practice and review of concepts aligned with the Math I grade level classroom instruction. All students have an iPad issued by
the county that they used to access Khan Academy online. If a student’s iPad was lost or being repaired, they used a laptop issued by the teacher. Classroom grades were given to both the treatment and control groups for their ‘warm up’ assignments. This is normal procedure and is done to encourage student participation in the activity. Each week the participating teachers with control group classes supplied the researcher with a copy of their ‘warm up’ assignments in order to determine how much, if any, remediation was done. ‘Warm up’ assignment grades for the treatment group were based on the number of skills mastered in Khan Academy each week. The purpose of this design was to see if fifteen minutes of in-class remediation of basic math skills using Khan Academy in place of regular classwork would increase math achievement.

During the Khan Academy student training, students were shown how to access Khan Academy, verify their coach, and pick an avatar. Once that was completed, they were shown how to start the first mission assigned by their coach. Missions in Khan Academy are created and reviewed by math teachers to guide learners through a specific content in a personalized way (Khan Academy, 2015). Khan Academy worked with Smarter Balanced Assessment Consortium to ensure that the missions were aligned with Common Core. Each mission checks the learner’s prerequisite skills with a short set of problems. When a learner has completed the mastery challenges and mastered all of the skills, the mission is completed (Khan Academy, 2015).

Initially, students in the treatment groups were assigned the Khan Academy Arithmetic mission. Upon starting the mission, students were given a short pretest in Khan Academy that assessed their individual learning needs. The researcher instructed their teacher/coach to notify her once a student completed the Arithmetic mission, who then gave the teacher the class code for the next mission, which was Pre-Algebra. Each time another student in the class completed
the first mission, the teacher gave them the new class code and notified the researcher. Both the Arithmetic and the Pre-Algebra missions cover 3-8 grade math content and are specifically designed for older students needing remediation due to gaps in their math knowledge. If students finished both of these missions before the end of the study, they were given a class code for the Algebra Basics mission. This was done so that the students would still be participating in the class warm up activity without having to provide them with something different for this portion of the class or for their grade. This mission reviews the foundational ideas of algebra, pre-algebra, and geometry (Khan Academy, 2015). So, it provided drill and practice of concepts currently being covered in their class within the Math I content.

Throughout the duration of the study, the researcher printed weekly progress reports from Khan Academy and gave them to the appropriate teachers for grading purposes, and to help teachers facilitate participation in the study. When all participating experimental group classes had completed both the Arithmetic and Pre-Algebra missions as verified by the researcher through the Khan Academy progress reports, all participating teachers of both groups were asked to administer the posttest, the North Carolina READY Math I End-of-Course Assessment, to their students on a specified date.

Data Analysis

This study hypothesized that statistically significant differences in mathematics achievement would be found for ninth grade math students based on level of instruction, i.e. grade level only and grade level plus remediation. Khan Academy, a supplemental online resource, was used to provide the remediation.

The pretest and the posttest used in this study was the North Carolina READY Math I End-of-Course Assessment. The posttest was the dependent variable for the study. The treatment, grade level instruction plus Khan Academy remediation, and the control, grade level
instruction, served as the independent variable. In the fall of 2016, all students in Math I were given the North Carolina READY Math I End-of-Course Assessment. The researcher collected the data and used the Statistical Package for the Social Sciences (SPSS) software version 22.0 to run the descriptive statistics on the data including the mean and standard deviation by level of instruction i.e., grade level only and grade level plus remediation. Table 3.4 shows a distribution of the students participating in the study.

Table 3.4

<table>
<thead>
<tr>
<th>Distribution of Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Grade level</td>
</tr>
<tr>
<td>Grade level + Khan Academy remediation</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

One internal threat to this design is that posttest differences could be attributed to pre-existing group differences rather than the treatment effect. Since the experiment lacked random assignment, the intent was to use analysis of covariance (ANCOVA) to make compensating adjustments to the posttest means of both groups in order to reduce the effects of any initial group differences (Gall, Gall, & Borg, 2007, p. 417). This was to test the statistical significance of the observed differences in mean scores for the treatment and the control groups. Posttest scores were used as the dependent variable, and the treatment was grade level instruction plus Khan Academy remediation, and the control, grade level instruction, served as the independent variable. Pretests scores were to be used as the covariate in the ANCOVA. In order to use ANCOVA, the following assumptions must hold for the data: normality, homogeneity of
variance, and for each independent variable, the relationship between the dependent variable (y) and the covariate (x) is linear with a homogeneity of regression slopes. According to Gall, Gall, and Borg (2007) histograms can be used to determine assumptions of normality since achievement results are continuous. For the homogeneity of variance, a Levine’s test can be used to verify that assumptions are equal among different samples. To ensure the homogeneity of regression slopes, scatter plots for linearity and univariate tests can be performed.

The data in this study failed to pass the assumptions necessary for ANCOVA. The histograms were non-normal and positively skewed, and the data failed the Levine’s test for homogeneity of variances. So, a nonparametric test, Mann-Whitney U, was used in the analysis to test the statistical significance of the posttest scores for the treatment and the control groups. An alpha level of .05 was used to determine whether to reject the null hypotheses.
CHAPTER FOUR: FINDINGS

Overview

In response to recommendations made by the federal government calling on all states to adopt standards in mathematics that produce college-and-career-ready high school graduates, curricular changes have occurred across the nation resulting in a more rigorous curriculum that does not include the review of prerequisite skills or the remediation of students who have gaps in their mathematical knowledge (U.S. Department of Education, 2011). Unfortunately, students enter ninth grade with mathematical skill deficits that tend to expand during high school. According to the National Center for Education Statistics (NCES), only 35% of eighth graders and 26% of twelfth graders scored at or above Proficient in mathematics (U.S. Department of Education, 2012). Research has shown that remediation works (Barh, 2008; Barh, 2010; James & Folorunso, 2012) and there is a need for cost-effective methods of math remediation for high school students.

The researcher used intact ninth grade student groups in established classrooms as the experiment and the control groups in this quasi-experimental, non-randomized control group research design. A Mann-Whitney U test was used to detect any differences in mathematics performance between the two different levels of instruction i.e., grade level only and grade level with remediation. A pretest was used to measure mathematical performance before treatment, and the same test was used as the posttest to measure the dependent variable—mathematical performance after the treatment. The pretest was administered in the fall of 2016 close to the beginning of the school year, and the posttest was given in May of 2017 at the end of the year. The tests were given to twelve ninth grade, Math I, classes from two different high schools.
Math I is the common core replacement for Algebra I. Six of the classes were assigned to the control group, and six were in the experimental group.

**Research Question**

**RQ1:** What is the effect of using Khan Academy as a supplemental online remediation tool on ninth grade students’ math achievement?

**Null Hypothesis**

**H₀₁:** There is no significant difference in the math achievement of ninth grade students who use Khan Academy as a supplemental remediation tool in addition to grade level instruction as opposed to ninth grade students who do not use Khan Academy as a remediation tool to supplement grade level instruction as measured by the North Carolina READY Math I End-of-Course Assessment.

The data collected in this study included the pre and posttest scores of the students and the percentage of completion of the two modules assigned in Khan Academy to the experiment group as the treatment. All statistical tests used an alpha of .05. The independent variable was participation in Khan Academy, and the dependent variable was mathematics performance as measured by the posttest.

**Descriptive Statistics**

First, the researcher screened the data for missing data and outliers. Any participants that failed to take both the pretest and the posttest were removed. Then, tests were performed in SPSS including descriptive statistics to test the assumptions for parametric statistics. Histograms revealed that while the control group posttest data was close to a normal distribution, the experiment group posttest data was not normally distributed. The posttest data for the
experiment group was positively skewed and contained several outliers. The posttest scores for the experiment group also failed the Levene’s test for homogeneity of variances.

The researcher screened the data again to determine if the outliers were the result of data entry errors, measurement errors, or were genuinely unusual data values. All of the pre and posttests were reviewed to rule out any grading errors. The instrument used for both the pre and posttest had a short answer section that was hand-graded and a multiple-choice section that was machine-graded. All of the hand-graded test sections for both the control and the experiment group were regraded for accuracy. When reviewing the machine-graded sections of the tests, two tests were found that had not been finished by the students. The researcher removed these records from the study. After the researcher made the corrections in SPSS and ran the descriptive statistics a second time, the control group posttest data was close to normal, but the experiment group posttest data was still positively skewed and not normally distributed. The experiment group posttest data also failed the Levene’s test. Box-and-whisker plots indicated that ten records appeared to be outliers. Table 4.1 shows the descriptive statistics for the data after the corrections. Since 13.5% of the experiment group were outliers and removing all of them significantly affected the results, the researcher took a closer look at the records within the experiment group to determine an appropriate course of action.

Table 4.1

Descriptive Statistics

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Median</th>
<th>Standard Deviation</th>
<th>Range</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (1)</td>
<td>58</td>
<td>24.25</td>
<td>24</td>
<td>6.21</td>
<td>26</td>
<td>38.58</td>
<td>6.21</td>
</tr>
<tr>
<td>Experiment (2)</td>
<td>74</td>
<td>29.30</td>
<td>24</td>
<td>15.59</td>
<td>76</td>
<td>2.38</td>
<td>5.33</td>
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</tbody>
</table>
The study originally planned for all of the experiment group participants to finish both the Arithmetic and the Pre-Algebra missions in Khan Academy at 100% before the posttest was given. When the data was sorted by the percent complete of the first Khan Academy mission, Arithmetic, only 8 students had completed 100% of the first mission. Although 92% of the experiment group completed more than half of the first mission, only 17 students, 23% of the group, completed 91-100% of the Arithmetic mission. Therefore, limited participation caused the treatment, Khan Academy, to be applied in varying degrees across the experiment group. Table 4.2 and Figure 2 show the different levels of completion of this first mission by the students in the study.

Table 4.2

*Khan Academy Mission One Experiment Group Completion Levels*

<table>
<thead>
<tr>
<th>Mission 1 Percent Complete</th>
<th>Number of Students</th>
<th>Percentage of Data in this range</th>
</tr>
</thead>
<tbody>
<tr>
<td>91 – 100%</td>
<td>17</td>
<td>23.61</td>
</tr>
<tr>
<td>81 – 90%</td>
<td>10</td>
<td>13.89</td>
</tr>
<tr>
<td>71 - 80%</td>
<td>13</td>
<td>18.06</td>
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<tr>
<td>61 – 70%</td>
<td>12</td>
<td>16.67</td>
</tr>
<tr>
<td>51 – 60%</td>
<td>16</td>
<td>22.22</td>
</tr>
<tr>
<td>41 – 50%</td>
<td>2</td>
<td>2.78</td>
</tr>
<tr>
<td>31 - 40%</td>
<td>2</td>
<td>2.78</td>
</tr>
<tr>
<td>21 – 30%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1 – 20%</td>
<td>2</td>
<td>2.78</td>
</tr>
</tbody>
</table>
Originally, the students in the experiment group were to be added to the second mission, Pre-Algebra, when they had reached 100% completion of the first mission, Arithmetic. During the course of the study, however, a problem arose involving wait times set up in Khan Academy for the Mastery Challenges. Students completing several Mastery Challenges within a short period of time received a message from Khan Academy alerting them that another Mastery Challenge would not be available for them for 8-24 hours. Mastery Challenges in Khan Academy allow students to gain skill mastery and increase the percent complete of the mission. According to the Khan Academy help center, these wait times are set up by Khan Academy to help learners retain the material they have learned before taking another Mastery Challenge. Since there is currently no way to get around the Mastery Challenge wait times, students were given access to the Pre-Algebra mission before reaching 100% completion of the Arithmetic mission so that they could continue to work on new concepts while waiting to take the Mastery Challenges.
Given this change, a Khan Academy variable was created to hold the sum of the Arithmetic and Pre-Algebra mission’s percent’s complete. This Khan Academy variable was used to evaluate the total Khan Academy participation of the students in the experiment group. The researcher sorted the data by the Khan Academy variable to organize the records by the degree that the treatment was applied within the experiment group. The researcher used the Khan Academy variable to help determine whether the posttest score outliers were genuinely unusual values based on level of treatment.

The researcher divided the data sorted by the Khan Academy variable into four subgroups based on the total Khan Academy participation (Table 4.3). Nine of the ten outliers in the experiment group were found in subgroups four and five and one at the upper end of subgroup three. The researcher determined then that the outliers were students who participated the most in Khan Academy and thus received the most treatment. Using SPSS, a chart was created showing the posttest scores for the control group (1) and the experiment group subgroups (2-4) (Figure 3). Based on this information, it was determined that removing the outliers from the data would eliminate students who had the most exposure to the treatment and thereby change the results of the study.

Table 4.3

<table>
<thead>
<tr>
<th>Groups</th>
<th>Number of Students</th>
<th>Khan Academy Participation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>17</td>
<td>17 – 85</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>86 – 114</td>
</tr>
<tr>
<td>4</td>
<td>19</td>
<td>117 – 137</td>
</tr>
<tr>
<td>5</td>
<td>19</td>
<td>143 – 197</td>
</tr>
</tbody>
</table>
Results

The researcher used a nonparametric Mann-Whitney U test to test the null hypothesis. Distributions of the posttest scores for the control and experiment groups were not similar, as assessed by visual inspection (Figure 4). Posttest scores for the control (mean rank = 61.45) and the experiment group (mean rank = 69.51) were not statistically significantly different, U = 1849.500, z = -1.211, p = .226, therefore, the researcher failed to reject the null hypothesis.
This chapter discusses and summarizes the study and the results. The chapter is divided into five sections: Discussion, Additional Analysis, Implications, Limitations, and Recommendations for Future Research.

**Discussion**

The purpose of this quasi-experimental study was to determine if using Khan Academy as math remediation would significantly affect student math achievement. This study used a static-group comparison design that included over 130 high school Math I students enrolled in two small rural high schools. The data were analyzed using Mann-Whitney U and revealed that there was no significant difference in the math achievement of the control and the experimental group posttest scores.

**Research question and null hypothesis.** The research question asked: What is the effect of using Khan Academy as a supplemental online remediation tool on ninth grade students’ math achievement? The null hypothesis stated: There is no significant difference in the math achievement of ninth grade students who use Khan Academy as a supplemental remediation tool in addition to grade level instruction as opposed to ninth grade students who do not use Khan Academy as a remediation tool to supplement grade level instruction as measured by the posttest. Based on the results of the Mann-Whitney U test the null hypothesis was retained. Students in the experimental group who used Khan Academy as a remediation for algebra prerequisite skills did not have statistically significant higher posttest scores than the control group who did not use Khan Academy.

**Additional Analysis**

Due to the varying levels of student participation in Khan Academy, different degrees of
treatment (Table 4.3) were applied to the experimental group. Further analysis was performed to investigate the difference between the posttest scores of the control group and the four experimental subgroups based on the total Khan Academy participation levels (Figure 3). Since assumptions were not met for t-tests, the researcher ran separate Mann-Whitney U tests comparing the control group to each of the four subgroups of the experiment group. The posttest scores of students in subgroup five were statistically significantly higher than that of the control group. Subgroup five contained the students with the highest Khan Academy participation (143-197) out of 200% possible completion across both missions. These were the students that had participated the most fully in the study and had come the closest to finishing both modules in Khan Academy. Therefore, students in group five received the most remediation of algebra prerequisite skills.

**Theoretical Framework.** The purpose of educational remediation is to fill in the gaps of missed content that is prerequisite to learning new content. It involves reteaching and reinforcing previously taught material. Remediation is grounded on the behaviorist theory developed by B. F. Skinner and is based on learning strategies, feedback or reinforcement, and resulting changes in behavior (Boylan & Saxon, 2015). Algebra I or Math I (CCSS) is a gateway course that is a required prerequisite for all subsequent mathematics courses in high school (U.S. Department of Education, 2008; Brown & Quinn, 2007). When a stand-alone remedial course is not an option, remediation needs to occur within grade-level mathematics courses by the ninth grade. This will help ensure that the prerequisites needed for learning algebra, including basic arithmetic, are mastered.

**Current Findings and Previous Studies.** While the results of this study did not show statistically significant higher posttest scores for the experimental group (Khan Academy users),
the results do support the existing studies and remediation theory as discussed in the literature review. For example, in a study by Wenner, Burn, and Baer (2011), geoscience course college students received mathematics remediation via supplemental online asynchronous learning modules. The researchers determined that the students who participated fully by completing the assigned modules were found to be the most successful. The current study, involving Khan Academy used as remediation, also showed that the students who participated fully by completing the highest percentages of the two assigned modules had higher posttest scores than the control group (Figure 3).

Khan Academy was developed and is still predominantly used as a one-on-one online math tutor for individual users outside of a classroom environment (Murphy, et. al., 2014). In September 2011, the Bill and Melinda Gates Foundation hired SRI International to explore using Khan Academy in the K-12 school environment. The two-year research study contracted by SRI International and conducted by Murphy, Gallagher, Krumm, Mislevy, and Hafter (2014) during the 2011-2012 and the 2012-2013 school years included nine sites, twenty schools, and over seventy teachers. The study involved piloting several different methods of using Khan Academy in the classroom as a supplemental educational resource (Murphy, et. al., 2014). Again, the results of the study indicated that students spending the most time in Khan Academy and those successfully completing the most problems experienced more positive outcomes including test scores and confidence level. One of the sites, a high school in a high-poverty area, used Khan Academy to meet an urgent need for math remediation for their students. This site used hand-picked Khan Academy modules to remediate gaps in students’ mathematical knowledge and modules to reinforce grade-level content that was being covered in the classroom (Murphy, et.
al., 2014). The study showed moderate to large differences in test scores after adding Khan Academy to the curriculum (Murphy, et. al., 2014).

**Implications**

Even though this study did not produce statically significant results, students who used Khan Academy had higher posttest scores, on average, than students in the control group. In most cases, the higher the student Khan Academy usage, the higher the resulting posttest score. Students in the experimental subgroups three, four, and five completed more of the two assigned modules in Khan Academy and thus received more of the treatment, remediation, than the control group and the students in subgroup two. As shown in Figure 3, students in subgroups three, four, and five of had higher posttest scores than the control and the lesser participating, subgroup two.

As stated earlier, the researcher used a separate Mann-Whitney U test to compare subgroup five to the control group and the results showed that there was a statistically significant difference between the two groups. The nineteen students in subgroup five completed 72-99% of the remediation content contained within the two assigned Khan Academy modules. These students received more of the treatment than any of the other students in the experiment group of the study. Therefore, they received the most remediation of algebra prerequisite skills. The posttest scores of subgroup five were significantly higher than that of the control group and of the lesser participating subgroup two. This implies that when students participate fully and use Khan Academy to remediate prerequisite skills that math achievement does improve. It also implies that the success of remediation is directly dependent upon student participation. This supports the results of the previously mentioned study by Wenner, Burn, and Baer (2011).

As stated earlier, there were ten outliers in the experiment group, and all were in
subgroups three, four, and five. Nine of those ten students were in the same class with the same teacher. They all had Khan Academy participation percentages of 86-194. This teacher gave the students the time they needed in class on a regular basis to work through the Khan Academy modules and was better at motivating the students to participate. This implies that the teacher also plays an important role in making remediation successful even when an online program is used. According to Bloom (1968), if students are given time, opportunity, and instruction meeting the current need and situation, 80% to 95% of students can achieve mastery. When using an online resource for remediation in a ninth-grade classroom, the teacher must supply the time and opportunity for the students to use the resource and motivate them to take advantage of it.

This study helps to fill a gap that exists in the current literature in regard to using Khan Academy in K-12 classrooms for remediation and using an online resource to remediate basic arithmetic and pre-algebra skills within ninth grade classrooms. Using a free, online program like Khan Academy for math remediation can put students in charge of their own learning and help increase student engagement and achievement (Light & Pierson, 2014).

**Limitations**

One limitation of a quasi-experimental study is that random sampling is not possible. Students in this study, however, were from two different high schools and were placed in their classes by a computer so, they were randomly placed in the Math I sections of both schools. A limitation of this study was that the demographics of the participants were strictly rural and did not include urban or suburban students. While there was some variation in the socioeconomic circumstances of the students, many are economically challenged. This study also had a limited number of African-American and Hispanic students and no Asian students. The local population
has a smaller minority population than other areas of the country and this was reflected in the student population participating in the study. Both schools were located in rural areas with many economically disadvantaged students and a broad range of socioeconomic situations.

Lack of student participation was another limitation of this study. Students were required to use Khan Academy for fifteen minutes a day, five days a week, or one hour and fifteen minutes per week. Many students did not use the Khan Academy as it was prescribed and did not complete the modules as was outlined in the original study. All of the teachers in this study taught the same CCSS, Math I content, but one teacher in particular was more effective at motivating the students to participate in Khan Academy. This teacher required that students spend the allotted time working in Khan Academy and consistently recorded grades for their participation. Most of the outliers in the data were students from this classroom. They had higher Khan Academy participation and higher posttest scores.

A final limitation of this study was the Khan Academy Mastery Challenges wait times. Students in the experimental group were not supposed to be given access to the second mission, Pre-Algebra, until they had reached 100% completion of the first mission, Arithmetic. In the course of the study, however, students began receiving messages from Khan Academy alerting them that another Mastery Challenge would not be available to them for 8-24 hours. These wait times were set up by Khan Academy to help ensure that students gained skill mastery before completing Mastery Challenges and moving on to new concepts. In Khan Academy the mission’s percent complete does not increase without completing Mastery Challenges, and there was no way to get around the wait times. Therefore, students were given access to the second mission, Pre-Algebra, before reaching 100% completion of the first mission, Arithmetic. This
allowed students to continue working in Khan Academy during class while waiting for the next Mastery Challenge to become available.

**Recommendations for Future Research**

Future studies are needed to determine whether Khan Academy improves student learning when used for remediation. A shorter study requiring students to complete the Pre-Algebra module only could possibly produce better results, especially if more control was exerted over student participation. Competition between classrooms and a reward system for completing sections of the module could help promote participation. The study should begin in the fall and end sometime between January and March before spring fever and student burn out that occurs at the end of the school year. Students in this study took their posttest too close to the end of the year and many of them did not put forth the same effort that they had on the pretest. This was reflected in some of their posttest scores being lower than their pretest scores.

Khan Academy also needs to be studied as a supplemental resource to provide drill and practice of grade-level concepts rather than for remediation only. Using an online program like Khan Academy for the practice of current content could produce different results than the remediation of past skills. Ideally, students would be placed in the Pre-Algebra module at the beginning of the year and then be advanced to the Algebra module at a set time to finish out the study with the posttest at the first of March, before spring break. This would be an interesting study combining some review and remediation of prerequisite skills followed by drill and practice of current algebra content.

Another interesting study would be to follow up with the experimental group of this study to see how many of these students are still using Khan Academy as an online math tutor when they are in the eleventh and twelfth grade. A questionnaire asking them if they are still
using Khan Academy and if they are using it for any subjects other than math would be an excellent tool for research. The researcher has noticed that some students from classes in 2015 are still accessing the program in 2018, three years after being introduced to it in the ninth grade. Once students learn to use the search feature in Khan Academy, many do continue to use it throughout high school and possibly in college as well. Further studies of high school students in urban and suburban areas with more diversity is also recommended.
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APPENDIX A

XXXXX High School
“Home of the Patriots”

999 XXXXX Road
P.O. Box 9999
XXXXX, WV 99999
999-999-9999

August 8, 2016

XXXX XXXXXX
Director of Secondary Schools or Principal
999 XXX Street
XXXXX, WV 99999

Dear Mr./Ms. XXXX:

As a graduate student in the School of Education at Liberty University, I am conducting research as part of the requirements for a doctorate in Curriculum and Instruction. The title of my research project is “The Impact of Khan Academy Math Remediation on Ninth Grade Student Achievement”. The purpose of the study is to determine whether receiving fifteen minutes a day of math remediation using the Khan Academy online program will significantly improve ninth grade student math achievement. The data will be used to determine the benefit of Khan Academy to remediate pre-algebra skills for ninth grade students when used as prescribed in the study.

I am writing to request your permission to conduct my research at XXXXX and XXXXX High Schools or at XXXXX High School in the fall of 2016. Participants will be presented with informed consent information prior to participating. Taking part in this study is completely voluntary, and participants are welcome to discontinue participation at any time.

Thank you for considering my request. If you choose to grant permission, please provide a signed statement on approved letterhead indicating your approval to Sandra Kelly at XXXXX High School. For your convenience I have included a detailed request form that may be copied onto letterhead.

Sincerely,

Sandra Kelly
Mathematics Teacher
XXXXXXX High School
(999) 999-9999
August 8, 2016

**Study Title:** The Impact of Khan Academy Math Remediation on Ninth Grade Student Achievement.

**Researcher:** Sandra L. Kelly

**Introduction:** XXXXX and XXXX High Schools have been asked to participate in an effort to ascertain the effectiveness of an online math program, Khan Academy, in the remediation of pre-algebra skills. This is part of a research study conducted by Sandra Kelly and supervised by Dr. Heidi Hunt-Ruiz from Liberty University in Lynchburg, Virginia.

**Purpose:** The purpose of this study is to determine whether receiving fifteen minutes a day of math remediation using Khan Academy during their regularly scheduled Math I class will significantly improve ninth grade student math achievement. The data will be used to determine the benefit of Khan Academy to remediate pre-algebra skills for ninth grade students when used as prescribed in the study.

**Procedures:** Ninth grade students will take a 50-question Math I pretest. Whole Math I classes will be assigned to either the experiment group or the control group. The experiment group classes will use Khan Academy as a 15-minute bell ringer activity at the beginning of each class period. They will complete both the Arithmetic and the Pre-Algebra missions in Khan Academy. The control group classes will use grade-level assignments chosen by their teacher for their bell ringer activities. When the experiment group classes have completed both missions in Khan Academy, both groups will take the Math I assessment again as a posttest.

**Potential Risks:** There are no foreseeable risks or potential harm to participants.

**Confidentiality:** The identity of the participants along with the test results and analyses will be secured in a locked file cabinet. When the research study is complete and all of the results have been reported and confirmed, all documents and identifying information will be destroyed.

**Dissemination:** The results of the study will be reported in a doctoral dissertation written by Ms. Kelly and stored in a database at Liberty University that is assessable to university students.

**Contacts and/or Questions:** All questions regarding the study may be sent to Sandra Kelly at skelly12@liberty.edu.
**Statement of Consent:** The signature below indicates the willingness of the XXXX County Board of Education or XXXXX High School to allow Ms. Kelly to conduct research at XXXXXX and XXXX High Schools as part of her educational requirements as a doctoral candidate at Liberty University School of Education.

______________________________  ________________
Director of Secondary Schools – XXXX County Schools  Date
or Principal of XXXXX High School
APPENDIX B

Teacher Introduction to Study

Fellow teachers, in an effort to serve our ninth grade students who are lacking some of the basic pre-algebra skills necessary to learn Math I, I will be conducting a study on the benefits of using Khan Academy as a remediation tool. Whole ninth grade classes will be assigned to either the control group or the experimental group and I ask your assistance monitoring students in both groups. The experimental group classes will receive a minimum of fifteen minutes per class period of Khan Academy remediation in lieu of a bell ringer assignment. Two Khan Academy missions, Basic Arithmetic and Pre-Algebra, in that order, will be assigned to those students. The study will not be complete until all participating students have completed both missions and taken the posttest. Any student that finishes both missions before the study is complete will be assigned the Algebra Basics mission. There will be nothing to grade or any planning necessary on your part. You will simply be asked to administer a Math I pretest prior to the study, ensure that the students participate as required, and administer the same Math I posttest at the end of study. For those of you monitoring a control group, you will be asked to refrain from using Khan Academy in your class during the time of the study and to provide copies of any bell ringer assignments that you use during that time. In order to facilitate full participation by the students in the experiment group, a grade should be given for skills mastered. A participation grade can also be given as deemed appropriate by the individual teacher to ensure that students are working for a minimum of fifteen minutes per class period in Khan Academy. I’ll provide you with a weekly status report from Khan Academy showing your students’ progress. The intent of the study is to determine if using Khan Academy specifically
for remediation and review of basic pre-algebra skills will help our ninth grade students master Math I content.
APPENDIX C

Khan Academy Teacher Presentation

Math teacher training

What is Khan Academy?
A nonprofit with a mission to provide a free world-class education for anyone, anywhere
Over 50,000,000 registered educators

Khan Academy offers...
• Video lessons across a wide range of subjects
• A deeply personalized experience in math, our focus for today

The Challenge
Reaching every student at their own level

The Solution
A personalized learning experience with content customized for each student

Learning with Khan Academy is....
• Personalized
• Mastery-based
• Engaging
Khan Academy offers...
Thousands of math exercises fully aligned to every Common Core standard for K-12
Created and reviewed by 40,000 educators: Khanacademy.org/educators

Khan Academy offers...
Thousands of math exercises stretching from 3rd through advanced calculus
Created and reviewed by 40,000 educators: Khanacademy.org/educators

Khan Academy offers...
Hints, supporting videos, and step-by-step solutions for every problem

Khan Academy offers...
Points, badges, and avatars to motivate students.

Khan Academy offers...
Actionable, real-time progress information for students, teachers, and parents

What is a mission?

- A way to focus students on grade-level content
- Recommended for all math implementations
- Accessible via SUBJECTS menu
Learning Dashboard

- Each practice skill focuses on one concept. Teachers can recommend skills.

Learning Dashboard

- Personal progress tracked.

Learning Dashboard

- Mastery challenges:
  - "Growth" of skills
  - Spread out over time to ensure retention
  - Help students accelerate through their progress

Leveling up

- Practice a skill
- Complete mastery challenges

Student Progress Report

- Total skills assessed in the Algebra section
Student Progress Report

- Shows who's struggling and which skills they're struggling with
- Use it to:
  - Assess your class's overall progress or a mission
  - Identify students who are struggling or excelling
  - Recommend skills to individual students

Skill Progress Report

- Compares different students' performance on the same skill
- Use it to:
  - Identify if/where many students are struggling with a skill and plan small-group lessons accordingly
  - Track your class's progress through a skill
  - Pair struggling students with peer tutors
  - Recommend skills to groups of students

Activity report

- Shows where students are spending their time
- Use it to:
  - Ensure that students are using Khan Academy time productively
  - See which students are working out on Khan Academy right now

Get started in your classroom

Check out Khan Academy's online resources at
https://www.khanacademy.org/teacher-sdk
"Start simple—just start"
APPENDIX D

Permission from North Carolina Public Schools

Request submitted 3/19/16 to http://www.ncpublicschools.org/newsroom/lets-talk/

Hello,

Your website, http://www.ncpublicschools.org/accountability/testing/releasedforms, grants permission to school systems, parents, and the general public to use released test forms for various educational purposes.

As a doctoral student at Liberty University I am interested in studying the effect of using Khan Academy as a remediation tool in Math I classes to increase student math achievement. This study will provide educators with a tool for remediating students who have gaps in their mathematical foundation. I have been searching for a reliable and valid Math I assessment to use as a pretest/posttest in my study.

May I use the released paper-and-pencil version of your EOC Math I test updated on 7/20/2015 as a pretest/posttest for my dissertation study?

Please feel free to contact me for more information. Also, if you are interested, I can provide you with a copy of the results of my study upon its completion.

Thank you in advance for your time in reading and responding to this request.

Sincerely,
Sandra Kelly

Sandra,
Thank you for your patience. I confirmed that you can use the released forms with the understanding the released forms and the information contained within must not be used for personal or financial gain.
I wish you the best of luck!
XXXX XXXXX

XXXX XXXXX
Department of Public Instruction
Accountability Services Division
Section Chief, Test Development Section
999-999-9999 (phone)
999-999-9999 (fax)
## APPENDIX E

### Common Core Standards Mapping by State

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* WV Math II Content Standard
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**North Carolina Math I Released Form 2012-2013 Answer Key**

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North Carolina Math I Released Form 2012-2013 Answer Key

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## APPENDIX G

### Unmapped Math I Common Core Standards

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<td>CCSS.MATH.CONTENT.HS.A.APR.A.1</td>
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<tr>
<td>Understand that polynomials form a system analogous to the</td>
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<tr>
<td>integers, namely, they are closed under the operations of</td>
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<tr>
<td>addition, subtraction, and multiplication; add, subtract,</td>
<td></td>
</tr>
<tr>
<td>and multiply polynomials.</td>
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<td>CCSS.MATH.CONTENT.HS.A.SSE.A.2</td>
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<tr>
<td>Use the structure of an expression to identify ways to</td>
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<tr>
<td>rewrite it. For example, see $x^4 - y^4$ as $(x^2)^2 -</td>
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<tr>
<td>(y^2)^2$, thus recognizing it as a difference of squares</td>
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<tr>
<td>that can be factored as $(x^2 - y^2)(x^2 + y^2)$.</td>
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<tr>
<td>Use the process of factoring and completing the square in a</td>
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<td>quadratic function to show zeros, extreme values, and</td>
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<tr>
<td>symmetry of the graph, and interpret these in terms of a</td>
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<tr>
<td>context.</td>
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<tr>
<td>Use the properties of exponents to interpret expressions for</td>
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<tr>
<td>exponential functions. For example, identify percent rate</td>
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<td>of change in functions such as $y = (1.02)^t$, $y = (0.97)^t$</td>
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<tr>
<td>$y = (1.01)^{12t}$, $y = (1.2)^{t/10}$, and classify them</td>
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<td>as representing exponential growth or decay.</td>
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<tr>
<td>Use volume formulas for cylinders, pyramids, cones, and</td>
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<td>spheres to solve problems.</td>
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<tr>
<td>Find the point on a directed line segment between two given</td>
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<td>points that partitions the segment in a given ratio.</td>
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<tr>
<td>Rewrite expressions involving radicals and rational</td>
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<tr>
<td>exponents using the properties of exponents.</td>
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APPENDIX H

2016 Math I Pacing Guide

Math I Contents

- Dimensional Analysis
- Solving One-Dimensional Equations and Inequalities
- Solving Absolute Value Equations and Inequalities
- Defining Functions
- Linear Functions
- Systems of Linear Equations and Inequalities
- Sequences and Series
- Exponential Functions
- Descriptive Statistics
- Geometry Topics

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<thead>
<tr>
<th>Math 1 Pacing Guide</th>
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<td><strong>Time</strong></td>
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<tr>
<td><strong>Statements for Students</strong></td>
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<td>3 Days</td>
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<p>| <strong>Unit: Expressions and Equations</strong> |</p>
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<th><strong>I Can…</strong></th>
<th><strong>Content</strong></th>
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<td>20 Days</td>
<td>M.1HS.4 Claim 1 TD</td>
<td>- Identify and understand the parts (terms, coefficients, factors) of an algebraic expression and their meaning</td>
<td>- Expressions- Parts, Coefficients, Terms&lt;br&gt;- Order of Operations&lt;br&gt;- Simplifying Expressions</td>
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|   | - Understand/use the order of operations with and without technology  
   | - Simply expressions (distribution and combining like terms utilizing exponent rules) | Exponent Rules- Review from 8th grade |
| M.1HS.5 M.1HS.6 Claim 1 TG M.1HS.7 M.1HS.27 Claim 1 TH M.1HS.28 Claim 1TI | - Write and solve one-step (linear, exponential, absolute value) equations in one variable  
   | - Write and solve one-step (linear, exponential, absolute value) inequalities in one variable  
   | - Write and solve multi-step (linear, absolute value) equations in one variable  
   | - Write and solve multi-step (linear, absolute value) inequalities in one variable  
   | - Use equations and inequalities to solve problems  
   | - Write (linear, exponential, absolute value) equations in two or more variables to represent a real-world problem  
   | - Graph (linear, exponential, absolute value) equations in two variables to represent a real-world problem choosing appropriate axes labels, scales and units  
   | - Explain and justify the steps to solve a simple linear equation  
   | - Solve linear equations and inequalities in one variable | One Step and Multistep Equations |
| M.1HS.8 | - Rearrange formulas to solve for a variable | Solving for a Variable |
| M.1HS.5 M.1HS.6 Claim 1 TG | - Write and solve one-step (linear, exponential, absolute value) equations in one variable  
   | - Write and solve one-step (linear, exponential, absolute value) inequalities in one variable | One Step and Multistep Inequalities |
| M.1HS.7  | · Write and solve multi-step (linear, absolute value) equations in one variable
| M.1HS.27 | · Write and solve multi-step (linear, absolute value) inequalities in one variable
| Claim 1  | · Use equations and inequalities to solve problems
| TH       | · Write (linear, exponential, absolute value) equations in two or more variables to represent a real-world problem
| M.1HS.28 | · Graph (linear, exponential, absolute value) equations in two variables to represent a real-world problem choosing appropriate axes labels, scales and units
| Claim 1 TI | · Explain and justify the steps to solve a simple linear equation
|         | · Solve linear equations and inequalities in one variable
| M.1HS.5 | · Write and solve one-step (linear, exponential, absolute value) equations in one variable
| M.1HS.6 | · Write and solve one-step (linear, exponential, absolute value) inequalities in one variable
| Claim 1 | · Write and solve multi-step (linear, absolute value) equations in one variable
| TG      | · Write (linear, exponential, absolute value) equations in two or more variables to represent a real-world problem
| M.1HS.7 | · Graph (linear, exponential, absolute value) equations in two variables to represent a real-world problem choosing appropriate axes labels, scales and units
|         | · Express constraint(s) using equations and inequalities and, when necessary, systems of equations and inequalities

### Absolute Value
- Equations
- Inequalities
Determine if a solution is appropriate/inappropriate based on the constraints

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Claim 1

**TM**  
A function is increasing, decreasing, positive or negative; relative maximums and minimums; symmetries; and behavior of the graph.

## Unit: Linear Functions

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<th>Content</th>
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|       | M.1HS.22  | recognize a vertical transformation  
|       |           | recognize even and odd functions from their graphs and algebraic expressions | Key Features - Parent Graph  
|       |           | Graphing through out (with table, x and y intercepts, slope intercept form) |  
|       |           | transformations | Inequalities  
|       |           | | Slope, Perpendicular, Parallel  
|       |           | | Writing equations- in different forms from different given data. (Standard Form, Slope-Intercept, Point-Slope)  
|       |           | | Modeling  
|       |           | | Arithmetic Sequences-relate to linear |

## Unit: Systems of Linear Equations and Inequalities

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|       | M.1HS.29  | solve a system of linear equations using elimination, substitution and graphing | Graphing  
|       | M.1.HS.30 | choose an appropriate method to solve a system of equations | Substitution  
|       |           | | Elimination  
|       |           | | Systems of Inequalities  
|       |           | | Applications |

## Unit: Sequences and Series

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|       | M.1HS.14  | define an arithmetic sequence | Arithmetic  
|       |           | define a geometric sequence | |

Statements for Students
Claim 1
TK
M.1HS.20
M.1HS.21
Claim 1
TN
- Recognize that (arithmetic, geometric) sequences are functions
- Use arithmetic to combine and build a new function
- Write arithmetic and geometric sequences both recursively and with an explicit formula
- Use arithmetic and geometric sequences to model situations
- Translate between the two forms

5 Days
M.1HS.14
Claim 1
TK
M.1.HS.20
M.1.HS.21
Claim 1
TN
- Define an arithmetic sequence
- Define a geometric sequence
- Recognize that (arithmetic, geometric) sequences are functions
- Use arithmetic to combine and build a new function
- Write arithmetic and geometric sequences both recursively and with an explicit formula
- Use arithmetic and geometric sequences to model situations
- Translate between the two forms

4 Days

Semester Review and Exams

Unit: Exponential Function

<table>
<thead>
<tr>
<th>Time</th>
<th>Standards</th>
<th>I Can…</th>
<th>Content</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>M.1HS.18</td>
<td>• Graph (linear, exponential) functions and show key features (intercepts; intervals where the function is increasing, decreasing, positive or negative; relative maximums and minimums; symmetries; and behavior) of the graph • Compare functions represented in different ways • Recognize a vertical transformation</td>
<td>• Key Features   Parent Function • Graphing • Transformations • Writing Equations • Solving Equations • Modeling  ➢ Growth and Decay ➢ Compound Interest</td>
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<tr>
<td>8 Days</td>
<td>M.1HS.19</td>
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<td>M.1HS.22</td>
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Recognize even and odd functions from their graphs and algebraic expressions

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<tr>
<th>Time</th>
<th>Standards</th>
<th>I Can…</th>
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<tbody>
<tr>
<td>20 Days</td>
<td>M.1HS.31, M.1HS.32, M.1HS.33, Claim 1 TP</td>
<td>Represent data with dot plots, histograms and box plots</td>
<td>Measures of Central Tendency</td>
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<td>M.1HS.34, M.1HS.35, M.1HS.36, M.1HS.37, M.1HS.38</td>
<td>Use methods to represent center of data (mean, median)</td>
<td>Standard Deviation/Range</td>
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<td>Determine the spread of data, standard deviation, and interquartile range</td>
<td>Dot Plot</td>
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<td>Choose the appropriate measure of center and spread based on the shape of data distribution to compare different data sets</td>
<td>Box Plot- Interquartile Range, Outliers,</td>
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<td>Define an extreme data point and outlier</td>
<td>Histograms-Frequency Tables (Single/Double)</td>
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<td>Interpret differences in shape, center and spread in the context of the data sets accounting for the effects of outliers</td>
<td>Describe Data- Shape, Outliers, Center Spread</td>
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<td>Summarize categorical data for two categories in two-way frequency tables</td>
<td>Scatter Plots- Linear Regression/ Best Fit, Correlation Coefficient</td>
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<td>Interpret relative frequencies in the context of data (joint, marginal, and conditional relative frequencies)</td>
<td>Correlation vs. Causation</td>
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<td>Recognize possible associations and trends in the data</td>
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<td>Represent data on a scatter plot and describe how they are related</td>
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<td>Fit function to a data and use it to solve problems</td>
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<td>Assess the fit of a function by analyzing residuals</td>
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<td>Interpret slope and intercept of a regression line in context</td>
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<td>Compute and interpret the correlation coefficient of a linear fit</td>
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• Distinguish between correlation and causation

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<tr>
<th>Unit: Geometry</th>
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<th>Standards</th>
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<td>Triangle Similarity</td>
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and use them to solve geometric problems

- Find the equation of a line parallel or perpendicular to a given line that passes through a given point
- Use coordinates to compute perimeters of polygons
- Use coordinates to compute areas of triangles and rectangles
- Connect the distance formula to the Pythagorean Theorem
APPENDIX I

Student Khan Academy Training

Student videos:

Motivational video introducing Khan Academy to the students:

Instructional video illustrating the student experience in Khan Academy:

Email link takes students to the following screen in Khan Academy.
Please enter your Username as your First+Last name.
After clicking “Sign Up”, the following screen will appear:

Click on your name in the upper right hand corner and then click on “Notifications”. You should see something like the following screen with mission “Arithmetic”.

Click on “Start this mission”.

On the next screen, click on “Get Started”.

Mission warm-up
Khan Academy wants to help you learn at your level.
Doing a few math problems helps us know where we can help. Give it a try!