MIXED METHOD STUDY OF THE IMPACT OF CALCULATOR USAGE ON 8TH AND 12TH GRADE STUDENTS' FUNDAMENTAL MATHEMATICAL SKILLS AND TEACHERS' PERCEPTIONS ON USING A CALCULATOR IN LEARNING MATHEMATICS

by

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Mixed Method Study of the Impact of Calculator Usage On 8th and 12th Grade Students' Fundamental Mathematical Skills and Teachers' Perceptions on Using a Calculator in Learning Mathematics

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ABSTRACT

Calculator usage in the United States is prevalent in secondary education classrooms. There has been a decline in mathematics achievement in national and international assessments for U.S. students. The U.S. historically introduces the calculator in mathematics classrooms earlier than several other countries, including: Singapore, Ireland, South Korea, Czech Republic, Austria and the Netherlands. This mixed methods study researches the potential impact of early calculator usage and fundamental mathematics skills in two ways: 1) a quantitative proctored mathematics assessment administered to middle and high school students, without access to calculators 2) qualitative semi-structured interviews from teachers to determine perceptions on student fundamental mathematics skills. Both the qualitative and the quantitative strands analyze the observations and insights on calculator usage in the classroom to determine student fundamental mathematics skills (FMS). The hypothesis for the study presumes there is no significant difference between 8th and 12th graders' scores on a fundamental mathematics skills assessment (FMSA), when assessed without the use of a calculator. However, this study shows that there is indeed a statistically significant difference between the two groups; the middle school 8th grade students had higher scores than the 12th graders on the (FMSA), as assessed without a calculator. Moreover, students believe they need calculators and teachers permit calculator usage, often without restriction (including exams), although teachers acknowledge limited FMS of students,

without a calculator. Teachers believe that FMS should be attained before 8^{th} grade. Without a firm foundation in the mastery of basic skills, it is difficult for students to move to higher levels of mathematics understanding. As a result, future research efforts will look at the elementary school level to see how far the early calculator usage extends and encompass comparison between elementary and middle school student FMS.

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CHAPTER 1: INTRODUCTION

Introduction to Research Topic

I have worked as a math instructor for 15 years at high schools, colleges and universities. Currently, I work as an academic advisor at a university and see students from their first year until they matriculate as seniors. While teaching mathematics at four different colleges, I saw the number of incoming freshmen students placing into developmental math courses soar. While working as a math instructor, a common theme was noted: many students had difficulty with fundamental math facts and they struggled with basic mathematical skills. Students were unsure of their multiplication facts for single-digit positive integers and they had challenges in determining percentages and reducing fractions. They were unsure of how to factor and solve equations. With a calculator, certain math topics had marginal success; however, even then, the results were inconsistent. Several students had conceptual difficulties with the addition and subtraction of positive and negative numbers. I wondered; how could this be? How can a student reach high school or college without the mastery of the basic fundamental mathematics skills?

When I expressed my concern with the lack of fundamental math skills, I was informed by the head of the math department in the largest school district in the state that these students were no longer required to memorize multiplication facts. Furthermore, I was instructed that students could now use their calculators because if they did not know their multiplication facts by now, they would never learn them. I think this is a low expectation of teachers and this resignation is not serving our students well. Additionally, I assume that students who reach for the calculator for the most rudimentary tasks are more likely to lack fundamental math skills. I discussed the dilemma in my classroom with colleagues and expressed concern about these startling trends. They were in the same situation in their own courses.

As a result, the first few math classes, in my course instruction, were spent reviewing as much of the fundamentals as possible. In order for students to have the opportunity for success in the course, I believed that review was necessary. After observing the lack of fundamental skills and the ramifications of this lack of basic knowledge, I wondered if this limited mathematical foundation was a pattern for other students and if this trend was indeed spreading. Although there is little literature on how the process occurs, I have discovered there is one major component that is consistent among students who lack fundamental math skills: calculator over usage during secondary education.

Recently, I spoke with students at both the high school and college level. The high school students shared with me that they consistently use calculators during class in high school and that includes during quizzes and on exams. College students have shared their struggle with mathematics as well, and have confirmed that they were not required to memorize multiplication facts at any point in their secondary mathematics education journey.

Similar to my experiences and observation, I have read multiple documents, stating that U.S. students have been trailing in mathematics achievement. The mediocre performance is not a new phenomenon but a problem that has existed over decades (Domina, 2014). U.S. student mathematics performance on standardized testing at the high school level, compared to their international counterparts, continues to be sluggish. The decline begins at the middle school level and subsequently pervades the entire high school journey (National Science Foundation, 2002). In this study, I explore one of potential factors, and the accompanying practices, that might affect students' fundamental mathematical skills.

Background of the Problem

Since 2009, the Common Core State Standards (CCSS) were developed and led by state leaders and commissioners of education. The impetus for this initiative was to help ensure that all students, regardless of what state they were in, would have the opportunity to succeed in college, career and life. The Common Core State Standards "describe what students should know and be able to do in each subject in each grade" (California Department of Education, 2016). The CCSS provides a detailed description of milestones and topics that each student should be capable of doing based on their year in school. According to the CCSS, by 8th grade, students should have the ability to solve linear equations, solve real-world and mathematical problems, approximate, as well as execute addition, subtraction, multiplication and division and perform ratio and proportional relationships. Although the Common Core State Standards were initiated in 2009 in order to increase the likelihood that students across the United States would meet the newly established benchmarks, the goal has not yet been attained. Many studies report that there is still a decline in U.S. students' mathematics achievement.

For example, the National Assessment of Educational Progress (NAEP) has measured students in several subjects at the state and district level including mathematics, science, reading and writing at grade levels 4, 8 and 12 (National Center for Education Statistics, 2015). According to NAEP results, for 2015, math scores declined for 4th grade, 8th grade and 12th grade. This dip across all grade levels occurred for the first time since the inception of the NAEP assessment in 1990 and reveals that most U.S. math students are not proficient in mathematics.

Likewise, Hanushek, Peterson and Woessmann (2014) assert that the United States is straggling in mathematics achievement compared to other countries. They examined the results of Programme for International Student Assessment (PISA) 2015, and compared U.S. students' mathematics achievement to other countries that are part of the Organization for Economic Cooperation and Development (OECD). Data analysis indicated that the United States placed below the average math scores by 20 points, indicating that the United States performed poorly overall. That meager performance was also seen in specific comparisons with advantaged students with high parental education, as well as economically disadvantaged students with low parental education.

Similarly, Sparks (2016) states that U.S. 15-year-olds did not perform significantly differently in science or reading on the PISA in 2015 compared with their showing in previous years, and their math performance significantly declined since 2012 and 2009, the last two times PISA was given. That put the United States roughly in the middle of education systems in reading and science on PISA, but below average in math (Sparks, 2016). Although there are examples of states that are doing relatively well, in particular, Massachusetts, Vermont, Minnesota, Colorado, New Jersey, and Montana, overall the United States places lower than most other countries in the assessment. U.S. math achievement ranks 28 out of the 34 nations comparing student mathematics proficiency with high parental education of OECD countries, and 20 out of the 34 nations comparing student math proficiency with low parental education of OECD countries.

Similar to the PISA results, the Trends in International Mathematics and Science Study (TIMSS) has assessed 4th and 8th grade students in mathematics and science, on an international level, every four years since 1995. The 2015 TIMSS results show that compared to 2011 assessments, United States mathematics achievement has not been reformed (National Center of Education Statistics, 2015). U.S. mathematics scores were below average for each of the categories.

As discussed above, multiple documents report that most U.S. students are not proficient in mathematics. Although the CCSS set out to improve academic achievement and impart specific standards and criteria for what students should be able to accomplish by grade levels, a significant improvement in terms of U.S. students' mathematics achievement was not observed yet. In other words, similar to my personal observation, national and international data indicate that U.S. students are not meeting the benchmark in mathematics. This study, therefore, explores potential factors that might impact the U.S. students' low achievement in mathematics, focusing particularly on their fundamental mathematics skills.

Need for the Study

Fundamental mathematics skills are critical to future mathematics success in other courses. Without the firm knowledge of the essential fundamental mathematics skills, other topics will be innately problematic for students. If students want to attend college or they are on a career path that requires a college degree, their career aspirations may be considerably limited if their fundamental mathematics skills are not solidified. "Most colleges want students with three years of high school math, and the more competitive colleges prefer four years," (The College Board, 2017, para. 5). Many degrees require students to take some type of mathematics course(s). As students mature and enter the workforce as adults, these skills are still necessary. Furthermore, fundamental math skills are crucial for a lifetime.

> Mastering mathematics is helpful in almost any career. Learning math helps workers analyze and solve problems—abilities that most employers value. And math teaches other important practices, including how to approach tasks methodically, pay attention to detail, and think abstractly. (National Labor Statistics, 2012, p. 2)

However, the fundamental mathematical skills are not something students automatically and intuitively attain. Instead, these skills should be educated and trained. In addition, there are multiple factors that might influence student knowledge and skills in learning mathematics. Of course, the determination of student mathematics performance in the United States can be a complex formula with numerous competing factors. Many studies examined and proposed some key factors including an opportunity gap, student expectation and math anxiety, economic factors competing for their time, and other internal and external factors.

First, there is an opportunity gap in the United States between the teacher quality of students with high socioeconomic status and those with low socioeconomic status (Akiba, LeTendre & Scribner, 2007). Based on the research, which included 46 countries, the United States had similarly qualified teachers as compared to the other nations; however, the gap between the teacher quality, based on socioeconomic status, the U.S. was at the highest levels in the world. In the U.S., the higher qualified teachers statistically report higher math achievement for students than teachers who are ranked as lower performers. The teachers with lower effectiveness are often conspicuously clustered in urban areas with underperforming schools with populations having low socioeconomic status (Adnot, Dee, Katz, & Wyckoff, 2017).

Secondly, student expectations and math anxiety are additional factors that can contribute to decreased mathematics achievement. Several students have low expectations about their intrinsic math aptitude and this apprehension can affect outcomes. Foley et al. (2017) expressed that the math anxiety, that students internalize, is negatively related to math performance and this is both within and across countries. Furthermore, stereotypes about mathematics also invade student perceptions, particularly if students endorse negative beliefs about their abilities in mathematics (Nasir, Royston, O'Connor & Wischnia, 2016). If students see their skills as subpar, they can withdraw from challenging concepts and advanced math courses.

Thirdly, students may have economic factors competing for their time. For example, the number of high school students who work in their freshmen year is close to 50%, and that number increases as students matriculate to higher grades with a peak of 87% of high school students working by their senior year (Department of Labor Statistics, 2005). These distractions can take away from time that could be spent on homework projects and reviewing mathematical topics. Lastly, other internal factors, which affect achievement in school, include feeling a sense of belonging and a belief in the importance of school while external factors include class failures, suspensions or expulsions (Ritchotte & Graefe, 2017).

As briefly discussed above, there are many factors that might influence fundamental mathematics skills that play a critical role in students' future mathematics success in other courses as well as in their career. However, very few studies have focused on the effect of calculator over usage on the fundamental mathematics skills of middle and high school students. Rohrabaugh (2016) states that in the U.S., the usage of calculators is of particular concern at the high school level, when calculator usage is especially rampant. Compared to other countries, the United States uses the calculator in mathematics instruction more than many other nations across the globe. More specifically, the United States has been increasing in its trend to introduce calculator usage in middle school (National Science Foundation, 2002) and solidify its use at the high school level (Safadi, 2016).

> The latest results of the Program for International Student Assessment showed Korea ranking fifth overall after Shanghai, followed by Singapore, Taiwan and Hong Kong. It was also the highest-ranked member of the Organization for Economic Cooperation and Development.
>
> Korea, Singapore, China and Japan, which ranked No. 2 among OECD members, all ban their students from using calculators. But the U.S., one of the most notable countries allowing calculators in class, finished 26th out of 34 OECD countries in math.
>
> Korea is not the only country that has debated the use of calculators in school. In 2012, the U.K. government banned the use of calculators for math tests on the state exam students take at age 11, starting in 2014.

> While U.K. officials acknowledged the benefits of calculators, they said they need to ensure that “students can perform calculations using efficient written methods” prior to using the tools.
>
> At the time, the U.K. had fallen to 26th place among OECD members in math achievement. (Min-Sik, 2015, para. 16-20)

Students may not have enough opportunity for repeated math practice, in the form of extensive fundamental math skills repetition, because of the increased calculator usage in secondary mathematics in the United States (Rohrabaugh & Cooper, 2016). Therefore, this leads to the hypothesis that U.S. students’ over usage of calculators might hinder their opportunities to build fundamental mathematics skills. For this reason, this study examines the U.S. students’ over usage of the calculator and its impact on their fundamental mathematics skills.

Purpose of the Study

The purpose of this study is twofold. First, this study quantitatively examines calculator usage effects in secondary education by comparing the fundamental math skills of 8th and 12th grade students. In this quantitative strand, this study seeks to determine the difference, if any, between the fundamental mathematical skills of the two grade level groups as a result of the increased calculator usage at the high school, which may cause limited opportunity for repeated math practice, in the form of extensive fundamental math skills repetition. Second, this study qualitatively explores secondary school math teachers’ perceptions on calculator usage in the classroom. For this mixed method study, the math assessment will be employed to specifically examine participating students’ fundamental math skills, and the semi-structured interview will be concurrently conducted to explore teachers’ perceptions on calculator usage in a math classroom and their instructional approaches for students learning mathematics.

Theoretical Framework

In his Cognitive Load Theory, Sweller (1994) argues that in human's cognitive process, "there are two learning mechanisms: schema acquisition and the transfer of learned procedures from controlled to automatic processing. It will be argued that intellectual mastery of any subject matter is overwhelmingly dependent on these two processes" (p. 296). These schemas involve how information is organized and learned. The classification of problems into categories or schemas is what enables students to determine how to process new information. Therefore, students need a frame of reference in order to learn new information. In the present study, schema, or frame of reference for categorizing problems, can be seen as the knowledge of fundamental math skills. Without this critical frame of reference (schema), higher order problems in mathematics will not have consistent success. That is, the process of "automatic processing" will not be able to be developed without foundational knowledge to support the learning process. In order for a student to leap from controlled to automatic processing and obtain mastery in any subject area, they must conceptualize and have the opportunity to investigate the topic from several angles and repeat the process again. Then, mastery can be cultivated.

Based upon Cognitive Load Theory, in order for students to grasp advanced levels of comprehension in mathematics, students must demonstrate fundamental mathematics skills. Some of those skills and comprehensions require repeated practice and memorization. Leung, Park Shimizu, and Xu (2015) found that many Asian countries, which show higher ranks in international comparison studies such as PISA and TIMSS, adopt an instructional approach that promotes students to engage in repetition and mastery learning for their fundamental mathematics skills. In this approach, students can study and seek knowledge through a lot of practice and memorization until they fully grasp the knowledge.

Maxwell (2016) also emphasizes this strategy of teaching, which is referred to as the mastery method that assists students in obtaining a level of excellence in proficiency. Maxwell further states that:

> A central concept in the Mastery Method is the development of a solid foundation in basic Mathematics ability, and this is established by focusing on a narrow set of core skills during the early years of education. Furthermore, students are supported in the development of each skill to the point where they have mastered the concept. When, and only when, students have mastered each concept can they be able to move on to the next skill. (Maxwell, 2016, para. 15)

He concluded that students in many Asian countries have excelled in math achievement through this method, compared to other industrialized nations. It is essential to review topics and to look at them from multiple angles and to solidify understanding before mastery is developed. Math students, in particular, benefit from repetition in order to perform problem solving and other types of mathematical assessments.

Furthermore, Montague, Krawec, Enders and Diet (2014) assert that cognitive processes, specifically involved for mathematical problem solving, are manifold and compounded by the organization of steps involved in the practice. Students benefit in math courses from the exercise of repetition and the layering of topics in order to reinforces concepts and develop the mastery that can be achieved and maintained over a lifetime. Savalia, Shukla and Bapi (2016) also note that cognitive skills are critical for a students' progress with repetition as part of that process of learning and the:

> …brain's ability to implicitly extract statistical regularities from the stream of stimuli and with attentional engagement organizing sequences explicitly and hierarchically. Similarly, sequences that need to be assembled purposively to accomplish a goal require engagement of attentional processes. With repetition, these goal-directed plans become habits with concomitant disengagement of attention. (Savalia, Shukla & Bapi, 2016, p. 1)

In other words, repeat encounters are paramount to mastery level learning, and studies in cognitive science have demonstrated this outcome (Kang, 2016). The key, according to the researcher, is to have repeat encounters with the material over a time period. If students are not repeating their cognitive abilities in fundamental math skills, the lack of repetition will adversely affect student math achievement. That is, the over usage of calculators may circumvent the cognitive process by stripping the opportunity for repetition, reflection and mastery of fundamental math skills.

Research Questions and Hypotheses

This mixed method study has two aims. First, this study quantitatively examines the impact of calculator over usage on secondary school students and then, qualitatively explores teachers' perceptions on calculator usage and their instructional approaches in mathematics classrooms.

According the Common Core State Standards (2017) students are expected to have the ability to perform the following mathematics skills by grade level eight, and beyond: work with radical and integer exponents, understand the connections between proportional relationships, lines, and linear equations, analyze and solve linear equations and pairs of simultaneous linear equations, define, evaluate, and compare functions and use functions to model relationships between. By grade level seven, all students are expected to have learned the following in previous years: ratios, place value and perform operations on integers including multiplication, division, subtraction and addition. This study identifies these skills as the fundamental mathematical skills. Each of these fundamental math skills are expected to be able to be problem-solved without calculator usage. However, for most of their high school mathematics learning, students have access to calculator usage in the typical U.S. math class. Even in many middle schools, calculator usage has been introduced in U.S. classrooms. As a result, this study raises a fundamental question of how students' over usages of calculators impact the fundamental mathematical skills that play a critical role in students' future mathematics success in other courses as well as in their future career. To better represent students' mathematics learning experiences in classrooms, this study also explores teachers' perceptions on calculator usage in the classroom, and their instructional approaches. Based upon two major purposes of the study, this study develops three research questions and a hypothesis for the quantitative research question as follows:

Quantitative Research Question: What is the difference in the fundamental mathematical skills between 8^{th} and 12^{th} grade students as measured by the Fundamental Mathematical Skills Assessment (FMSA)?

Hypothesis: There is no significant difference between 8^{th} and 12^{th} graders' scores on the FMSA when assessed without the use of a calculator.

Qualitative Research Question: How do secondary school math teachers perceive calculator usage in their mathematics teaching, and how do they describe their experiences in teaching and learning of mathematics in terms of necessary repeated practice for fundamental mathematical skills?

Mixed Methods Research Questions: How can higher education leaders address the long-term impact of the incorporation of calculator usage in U.S. secondary mathematics**?**

Importance of the Study

The current state of mathematics for U.S. students is in a decline (National Science Foundation, 2002). Educational leaders have begun to look at ways to increase the level of mathematics achievement of U.S. students. Several of these efforts are focused on Science, Technology, Engineering and Math (STEM) fields of study and instruction. The U.S. Department of Education (n.d.) stressed the importance of these fields of study and students' ability to solve tough problems, if equipped with innovation skills that work in conjunction with advanced knowledge. In order for students to excel in each of these four areas of study, fundamental math skills are the gatekeepers to the programs. Without fundamental math skills, these careers have virtually closed doors.

This study aims to add value to the body of literature concerning math achievement in a substantive investigation on how calculator over usage may negatively impact fundamental mathematics skills in secondary education. Current literature and national rankings list the achievement gap between the United States and several other countries (National Center for Educational Statistics, 2015), while this study seeks to offer some solutions on ways the gap may be reduced. As a result of this investigation, educational leaders may develop a more expanded knowledge of the pivotal importance of fundamental mathematics skills for all mathematics students and cultivate a greater sense of urgency in accepting new methodologies in mathematics instruction.

If there are improvements at the fundamental level in students' math understanding, there can be greater opportunity for future mathematics success in other courses as well as in student career options. Without the foundation of mathematics skills being strengthened, there is little hope for improvement in mathematics achievement because mathematical concepts require a solid foundation to build on before other topics can take root (Perna & Loughan, 2014). The learning goal for mathematics instruction is to teach skills that can be built upon and developed into sound problem solving strategies. These cognitive skills require repetition to reinforce and demonstrate content knowledge and a mastery level of understanding (Kang, 2016). If the United States is to compete globally and have a stronger foundation for students, change is necessary. This study is central to the growing awareness of the criticality of mathematics skills.

In addition, the assessments and interviews are designed to provide first-hand knowledge and data of what practices exist in the classroom and what concerns teachers have for their students. These results and findings will add to the limited body of literature on the impact of widespread calculator usage in secondary education. The goal is to isolate trends which may negatively impact students and use that testimony to generate potential solutions and recommendations to educational leaders. In the current structure of secondary education, many students are leaving their high school mathematics course and performing poorly on the college mathematics placement exam (Ngo & Melguizo, 2016). When students have a mathematics placement into a developmental course, their education now has added costs and added timing for degree completion (Valentine, Konstantopoulos, & Goldrick-Rab, 2017). According to the National Center for Educational Statistics (2013) the national average of developmental courses for first year freshmen students averaged over 20 percent. In a subsequent report, the number of first and second year students who took at least one developmental course rose to about 1/3 of students (National Center for Educational Statistics, 2016). Students who take developmental courses are not only potentially extending their college journey to matriculation, they are taking courses that are not part of the credits for graduation. Furthermore, unfortunately, the pass rate in these courses is particularly dismal (Gaertner, Kim, Desjardins, & Mcclarty, 2014). As a result, developmental mathematics courses extend the time before students are eligible for college-level math courses. If they do not pass the developmental course at its inception, that increases the time between college acceptance and college math readiness, which can significantly extend the expected four years of a college degree and ultimately, the tuition costs. This cycle can be particularly frustrating to students. Also, it must be made clear that developmental mathematics courses offered at universities and colleges cover content from the high school and middle school curriculum mathematics level. These courses commonly prohibit calculator usage, as does the mathematics placement exam offered at the postsecondary institution. Therefore, the calculator component of this study, as it relates to fundamental mathematics skills, firmly ties in with the dilemma in student mathematics achievement.

Relevance to Educational Leadership

Instructional leadership theory historically emphasizes the crucial leadership of the principal in terms of setting goals for the institution and for the supervision of the teaching curriculum; however, recently the research has grown to incorporate the role of teachers and support staff in the development of teaching plans and in the creation of a positive and distraction-free learning climate (Robinson, Lloyd, & Rowe, 2008). As educational leaders are informed, through professional development, of the profound impact of fundamental mathematics skills and how this foundation in key content areas is crucial for subsequent mathematics progression, the focus on mathematics instruction in terms of demonstrating these fundamental skills has a better opportunity to succeed. Investigators and researchers can post the problems that exist in terms of national mathematics rankings between the United States and other countries; however, if educational leaders do not fully comprehend the magnitude of the problem and how early the deficit may be detected, they may choose strategies that up until now have shown minimal evidence of effectively working. Year after year much money is spent on solutions that have thus far not shown overall improvement in the students' application of fundamental mathematics skills. No economic strategy seems to be as prolific as fueling funds into technology to solve achievement gaps in mathematics skills. As early as the late 1990's there was concern as to technology being perceived as the solution to virtually all academic challenges. Although this was written over 20 years ago, this still has a significant concern today, in terms of how technology is still often seen as the answer to educational improvement challenges:

> Education has always been susceptible to "silver bullet" solutions to its problems, and imposing a new technology has often been such a solution. Yet time after time, the "technology du jour" has collided with the realities of the classroom and resulted in only marginal changes in how teachers teach and students learn. (Coley, Cradler, & Engel, 1997, p. 9)

There appears to be no substitute for learning fundamental mathematics skills, other than taking the time to understand and absorb them.

With the pressure to alleviate the educational achievement gap in mathematics, technology is applied to solve student learning concerns. The technology may take the form of: graphing calculators as well as internet access to support online capabilities, mathematics videos and online tutorials, multimedia computers and similar technology are placed into mathematics classrooms. However, the absence of fundamental mathematics skills will not materialize to a student simply because they may have a technological tool. These tools can be an excellent source of supplement, or in some cases an option for direct instruction reinforcement; however, with the advent of these technologies, the data reports that the skill levels of students is not improving at the speed of the technological advances. Therefore, it takes educational leaders skilled in not only the current trends in improving the achievement gap, but aware of the effectiveness and limitations of those trends. Instructional leadership theory stresses the professional development of the leader and the ability of the leader to influence and coach their institution's teachers and staff (Boston, Henrick, Lynsey, Gibbons, Berebitsky, & Colby, 2016).

Therefore, if principals and other leadership decision makers determine that fundamental mathematics skills are crucial to mathematics progression, then they will support the incorporation of techniques to improve these skills. If these fundamental mathematics skills are deemed crucial requirements before a student can progress mathematically, then curricula would necessitate a design with a repetition component. This component would intrinsically be an integral part of the design as a critical element in the scope of mathematics education. This intervention would then be the standard protocol and not the exception. That is why instructional leadership theory is so strongly tied to this study.

However, leaders will need to acquire the knowledge and the aptitude to solve problems efficiently and sustainably. Educational leaders must see the intrinsic value of fundamental math skills. Overuse of the calculator and the lack of repetition in the classroom is a trend that has not resulted in increased mathematics achievement for our students.

Educational leaders are trained to anticipate the needs of the students, oversee instruction and curricula, as well as create an environment conducive to learning. Instructional leadership also encompasses the importance of defining and clearly articulating a school's mission and vision.

> Defining the school's mission includes working with the staff to ensure that the school has clear and measurable goals that are clearly communicated throughout the school community. These goals are primarily concerned with the academic progress of the students. Managing the instructional program requires the school principal to be deeply

> involved in the school's curriculum, which includes supervising instruction in the classroom, managing the curriculum, and monitoring students' progress. The principal also leads improvement of the school's climate by ensuring there is a high standard of excellence, with high expectations adopted by the school community. This includes providing incentives for students and staff, maintaining visibility, as well as protecting the time needed for classroom instruction from being consumed by managerial duties. (Shatzer, Caldarella, Hallam, & Brown, 2013)

As leaders make changes, the goal is to take steps that are measurable and focused to impact student achievement and:

> …are distinct from more prevalent traditional practices in that they support students to engage in cognitively demanding tasks and construct solutions to tasks that require students to make sense of the mathematical relationships at hand. Teaching ambitious mathematics, then, requires a deep understanding of the mathematical content, an understanding of the various ways in which students solve tasks for a given topic. (Rigby, Larbi-Cherif, Rosenquist, Sharpe, Cobb, & Smith, 2017, p. 638)

The leader has to be willing to create a shift in the current trajectory of mathematics education to produce positive and sustainable results.

Definition of Terms

Calculator Over Usage – Incorporation of calculator usage, within secondary education, for fundamental mathematics skills topics including: addition, subtraction, introductory problem solving, place value identification, multiplication and division, measurement and geometry, understanding number operation in base ten and fractions, ratios and proportional relationships, early expressions and equations, calculation of rational numbers, statistics and probability.

Common Core State Standards (CCSS) – State education chiefs and governors in 48 states came together to develop the Common Core, a set of clear college- and career-ready standards for kindergarten through 12th grade in English language arts/literacy and mathematics.

Today, 42 states and the District of Columbia have voluntarily adopted and are working to implement the standards, which are designed to ensure that students graduating from high school are prepared to take credit bearing introductory courses in two- or four-year college programs or enter the workforce (Common Core State Standards Initiative, 2017).

Early Calculator Usage – Incorporation of calculator usage for students who are learning basic mathematics skills including: addition, subtraction, introductory problem solving, place value identification, multiplication and division, measurement and geometry, understanding number operation in base ten and fractions.

Fundamental Mathematics Skills – These are the primary skills according to the Common Core State Standards (CCSS) that students are required to know. These mathematics skills are expected to be taught and reinforced in progression from K-7th grade. These skills include the introduction of the following concepts with a focus on the ability to: perform addition, subtraction, problem solve and identify place value as well as begin operations and algebraic thinking (grades K-2), perform multiplication and division, measurement and geometry, understand number operation in base ten and fractions (grades 3-5), ratios and proportional relationships, early expressions and equations, calculation of rational numbers, statistics and probability (grades 6-7), (Common Core State Standards Initiative, 2018).

Fundamental Math Skills Assessment (FMSA) – Assessment created by the investigator according to the Common Core State Standards for students K – 7th grade level in mathematics, designed to measure the ability of students to solve equations and recognize expressions, solve basic geometry problems and understand introductory statistics and fundamental probability without a calculator at the 12th grade level compared to the ability to solve the same types of math problems at the 8th grade level.

Delimitations

This study focuses on the assessment of students who are specifically in either 8th grade or 12th grade. The participants will be students from schools within the northeast region of the United States. The majority of the high school student participants are from urban settings of which 38% are considered low-income with a total student body comprising of 52% black, 32% white, 11% Hispanic , 3% Asian and 2% multi-racial; the majority of the middle school student participants are from urban settings of which 55% are considered low-income with a total student body comprising of 55% black, 24% white, 12% Hispanic , 4% Asian and 8% multi-racial (Delaware Department of Education, 2017).

This mixed methods research will exclusively investigate secondary school students' fundamental math skills and calculator usage in the classroom. The focus will be on the difference between the two grade levels' skills assessment based on the rampant use of calculators throughout high school in the United States (Mao, White, Sadler & Sonnert, 2017). Therefore, this study will not look at expected math skills for students beyond eighth grade. In other words, the research is centered on the fundamental math skill ability obtained, and retained, in the progression from kindergarten up to 7th grade. Development of the fundamental skills in mathematics is the focus of this research.

Although included in the study, the focus is not geared on ethnicity. There may likely be a significant number of participants of the study who will be considered minority students. However, the study is geared to see how math skills have increased or diminished for all 8th and 12 grade students. Additionally, non-traditional students will not be a part of this study. Based on theories of adult learning, there are some nuances in adult learners that may not exist in traditional students covering the exact same mathematical concepts (Bates, 2017). Therefore, adult students, who are completing their high school credentials, years after leaving middle or high school, are not included in this study. Furthermore, children who are homeschooled will not be participants of this study. The researcher is specifically looking at students who participate in the traditional school curriculum and experience in the United States. Therefore, only students who are in public or charter schools will be eligible participants in this study.

Limitations

There are inherent limitations to this study. The number of participants will be a small sample. The plan is to have at least 100 students who are in the 8th grade along with an additional 100 students in the 12th grade for a grand total of at least 200 participants. That is a small sample compared to the total population of 8th and 12th grade students. The limited number of students is based on the travel restrictions in this study as well as the limited window of time allotted to collect and analyze data.

Furthermore, this study will not have control on which students decide to participate in the study. Students will be able to decline participation. Although the researcher would aspire to have all students in the region partake in the present study, only those willing students will be assessed. Students from various backgrounds and ethnicities will be included in the study and they will have the opportunity to freely express their experiences in the survey questions of the instrument. Their comments and experiences will not be filtered. Each student's contribution will be received and included in the study, individually and collectively.

In addition, this study, because of the nature of the interviews of the small group of teachers, is not generalizable. Each teacher participant's experience is taken into consideration.

The student participants will have unique interactions with their teachers and the teacher will have unique opportunities to share their thought and perceptions. These different influences create a wealth of information for examination. It is the responsibility of the principal investigator to determine commonalities and consistent data between individuals that can be grouped.

Summary of Chapter I

The United States has experienced increasing challenges in the math achievement of students. There have been efforts to bridge the gap, including the extensive plan to standardize the curriculum of students with the Common Core State Standards. However, even with the increased planning and the incorporation of additional technologies in the classroom, cracks in the foundation of fundamental math skills still exist for many students.

Although there are various factors that impact the fundamental math skills of students, this present study focuses on calculator usage across the United States in secondary mathematics. Calculator over usage in secondary school mathematics learning is unique to the United States, in comparison to other countries, and might impact students' limited opportunities for repeated math practices and necessary memorization to advance their knowledge and skills in mathematics. Based on cognitive load theory, this study employs a mixed methods research design to quantitatively look at the fundamental math skills of secondary school students and qualitatively explore teachers' perceptions on calculator usage in the classroom and their teaching and learning experiences in mathematics.

CHAPTER 2: REVIEW OF THE LITERATURE

Introduction

In this chapter, current trends and issues of math education will be discussed. First, the current status of U.S. students' achievement in mathematics will be discussed by reviewing the results of international standardized math testing and the ranking of the United States in comparison to other countries. Math achievement of U.S. students will be further reviewed both domestically and internationally. Second, how students learn, build on concepts, and retain knowledge will be shortly reviewed. Next, the differences between the U.S. mathematics instructional styles and other countries' will be reviewed, focusing particularly on calculator usage in classrooms. Finally, the incorporation of recent changes in U.S. mathematics education will be explored along with the current state of achievement of graduating high school math students.

The Trends in International Mathematics and Science Study (TIMSS) has been testing students in 4^{th} and 8^{th} grade since 1995. This study assesses students in math and science every four years and is conducted across national lines. Out of 48 countries, the United States was in the top 70% of ranked countries at the 4^{th} grade level and out of 39 countries, the United States rank was still in the top 70% at the 8^{th} grade level, according to 2015 TIMSS results. However, by the time students reach high school those results are not at the same level for many U.S. students and the decline in mathematics is most marked after students are in high school. This trend is found within the result of another international test, known as the Programme for International Student Assessment.

> One of the biggest cross-national tests is the Programme for International Student Assessment (PISA), which every three years measures reading ability, math and science literacy and other key skills among 15-year-olds in dozens of developed and developing countries. The 2015 the Programme for International Student Assessment (PISA), the U.S. students' math achievements were placed an unimpressive 38th out of 71 countries in math and 24th in science. Among the 35 members of the Organization for Economic Cooperation and Development (OECD), which sponsors the PISA initiative, the U.S. ranked 30th in math and 19th in science. (DeSilver, 2017, para. 2)

The results above place the United States in the bottom 47 percent in math for PISA and at the bottom 15 percent in math for the OECD. The United States has been trailing Asian countries in particular. In the mathematics ranking established by the OECD of participating countries, Korea and Japan are consistently ranked in the top five (Hanushek, Peterson & Woessmann, 2014). These top spots are consistent regardless of whether the countries are ranked overall, or separated by proficiency levels with low parental education. Even when separated by proficiency levels with high parental education, the United States ranks at its lowest spot of 28, for the 34 participating countries.

This trend is also found in many assessment documents in the U.S. For instance, the National Assessment of Educational Progress (NAEP), which is the national test of the Federal Education Department, is referred to as the report card for the United States. The assessment measures students in several subjects at the state and district level including mathematics, science, reading and writing at grade levels 4, 8 and 12 (National Center for Education Statistics, 2015). The assessment began in 1990 and for the first time in mathematics, the United States scores dipped in 2015 for grades 4, 8 and 12 from the preceding year of assessment. That is a distinct decline because although the 4th and 8th grade students may compare stronger internationally, even those grade scores are beginning to dip from previous assessments.

Typically, until 2015, 4th grade and 8th grade math scores had small incremental increase, or at least stayed consistent. For the first time the scores declined in each of the assessed grade years in mathematics.

Furthermore, although student scores for 4th and 8th grade U.S. math students are stronger internationally, it does not mean that most of the students are proficient in mathematics. Even with the higher ranking internationally at these grade levels, most U.S. math students are not proficient in mathematics.

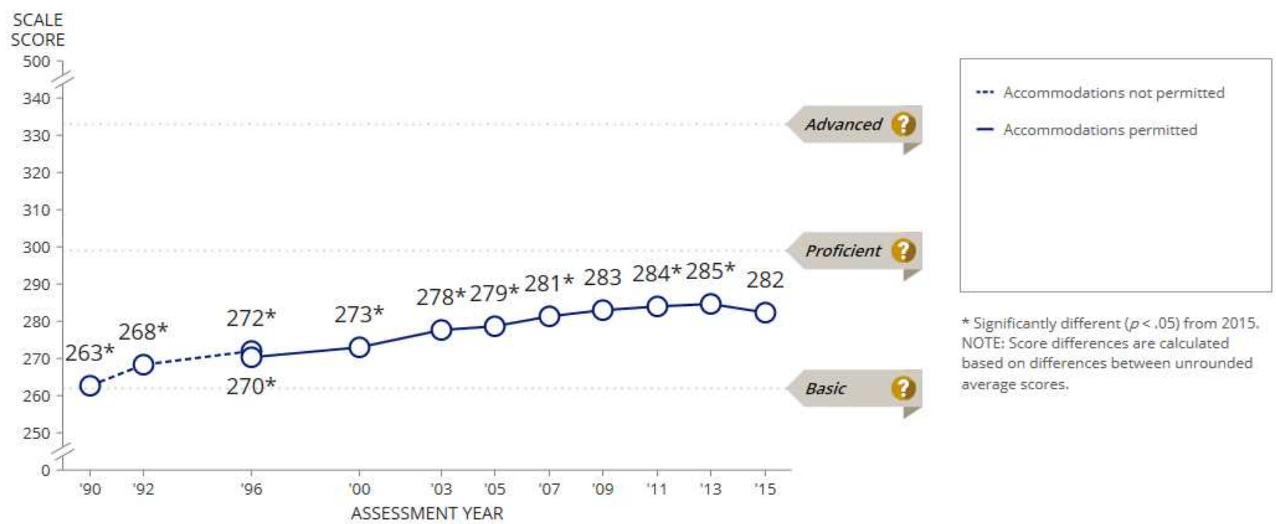

Figure 1. Trend in Eighth Grade NAEP Mathematics Average Scores, (National Assessment of Educational Progress, 2015).

Cognitive Domains Required for Fundamental Mathematics Skills

As early as the 1980's, the unease with U.S. mathematics education was a serious concern for educators and researchers since the students in America were straggling students in other nations in mathematics. The American mathematics curriculum was already being challenged, as was the limited amount of time spent on mathematics compared to other subjects in relation to other countries, particularly Asian countries (Stevenson, 1987). Differing from the U.S., many Asian countries typically share a curriculum across national lines (Leung, n.d.). If students are studying a particular topic in one part of the country, the educational resources are fairly consistent across that country and teachers have the opportunity to collectively improve. Furthermore, in Asian countries, math teachers have a culture that fosters an exchange between teachers and strategies to improve instruction. Specifically, there is a tradition of “handing down” the best practices in education. American instruction also has interaction between instructors to improve teaching; however, it is typically more formal in terms of professional development efforts (Kennedy, 2016).

Handing down best practices has an advantage for instruction in that only practices that work and have been working are continued. These practices can be fine-tuned to meet student needs and to enhance instruction. Of course, professional development is also designed to foster best practices by communicating successful strategies. However, in some cases, formal trainings of new requirements or new initiatives may envelope the time spent in professional development. Competing priorities may limit the actual “handing down” of techniques.

There are cognitive domains required for students in order to be successful at the 4th and 8th grade math grade and “being aware of learning styles and their influence on different cognitive domains may provide educators with ideas for differentiating instruction and may help improve TIMSS achievement” (Kablan & Kaya, 2013, p. 97). These domains include: knowing items, applying knowledge and the ability to reason (Nixon & Barth, 2014). *Knowing* requires students to remember facts or procedures. The knowing particularly relates to the ability of students to quickly recall a mathematical frame of reference or to readily ascertain a mathematical concept or symbol. Students’ ability to decipher information presented in a simple table or graph, the recognition of a group of numbers ordered in a list or the ability to determine elapsed time is all a part of knowing. *Applying* requires that students use knowledge to solve a science or mathematics problem. Applying relates to the ability to select methods or strategies for problem solving. The implementation of skills and the ability to analyze the validity of solutions is all a part of applying. Via *Reasoning*, students must find solutions to complex, multi-step problems in unfamiliar contexts. Reasoning is the ability to work in a step by step format even when there may be no concrete detailed instructions. Students who can reason have the ability to solve problems they may not see on a regular basis via their knowledge and application of that knowledge.

All of these components make up the components of the cognitive domain (Ministry of Education, 2011). In order to reach the mastery level of fundamental math skills, students must be able to use their cognitive domain to concretely apply principles to solve a myriad of different styles of questions. This cognitive domain is critical to problem solving. Students who succeed in math have the ability to look at math questions with different types of formats and extract their knowledge from their domain of math skills and apply them to the mathematics problems. This type of understanding is necessary in order to logically obtain solutions in multiple frameworks.

In many Asian cultures, mathematics is taught with a focus on repetition, in fundamental concepts. The process of learning often starts with gaining competence in the procedure, and then through repeated practice, students gain understanding (Leung, n.d., p.43). Repeated practice is a staple for students in Asian countries. This type of repetition is designed to promote mastery of knowledge and skills. After many repetitions and practice, concepts are more firmly established. Then, more complex and higher order topics are added for students to problem-solve in order to cultivate a deep level of understanding of mathematical topics.

U.S. Calculator Usage

The National Science Foundation (NSF) presented an important perspective on comparing calculator usage in the United States and in other countries. The evaluation showed the percentage of students who use calculators in secondary education as well as their math scores. Countries with increased calculator usage had lower scores than those who did not, according to the NSF (2002). Calculator usage in math courses is consistently promoted in the American classroom (Horton, 2004). The trend to use calculators has increased in several types of curriculums over the last 25 years.

U.S. mathematics programs have undergone several transformations in order to compete in the global marketplace, especially with Asian countries like China and Korea. These countries have established some consistent math achievement in mathematics average scores in primary education across the region. At the secondary school level, graphing calculators continue to be a focal point in math curriculums in the United States (Horton, 2004). However, in primary and in secondary education, several competing cultures do not use calculators in class, especially at the 4th grade level. The primary mathematical years between 4^{th} and 8^{th} grade is a critical time for students to develop number sense and acquire and expand on the abilities necessary for a firm fundamental mathematics foundation (Nelson, Parker, & Zaslofsky, 2016). These abilities specifically include: the ability to add, perform subtraction of positive and negative numbers, as well as multiply and divide, perform ratios and understand decimals (CCSS, 2017). The data reveals that the later the calculator is introduced to the student, the stronger the average mathematics score is for the student (National Science Foundation, 1995). Table 1 gives a historical and detailed view of the 4^{th} and 8^{th} grade student mathematics score, comparing hand-held calculator usage and non-usage by country.

Table 1

4th and 8th Grade Student Mathematics Score Comparing Hand-Held Calculator Usage and Non-Usage by Country (NSF, 1995)

			Calculator Use and Access (%)						
	Average Mathematics Score (Mean)		4th Grade Students		4th Grade Teachers		8th Grade Teachers		
Country	4th Grade	8th Grade	Have calculators at home	Never Use in Class	Never Use in Class	Use for Complex Problems	Never Use in Class	Use Daily	Use for Complex Problems
Singapore	625	643	93	96	97	1	1	82	82
South Korea	611	607	87	93	86	3	76	1	4
Netherlands	577	541	93	90	85	2	0	81	67
Czech Republic	567	564	95	63	54	8	3	74	80
Austria	559	539	95	96	98	0	2	87	70
Ireland	550	527	95	91	88	3	68	11	7
United States	545	500	95	34	29	26	8	62	76
Hungary	548	537	95	90	78	5	29	60	53
Canada	532	527	95	51	37	23	5	80	86
England	513	506	95	15	8	28	0	83	73
Norway	502	503	95	89	93	1	2	82	72
New Zealand	499	508	95	18	5	50	7	66	70

Initially, one may discount this data in its archived status as being irrelevant. However, as with many systemic issues that seem insurmountable with quick fixes, there are warning signs before larger problems manifest. In this case, as early as 1995 there was concern about the potential risk involved in the incorporation of calculator usage at such a young stage of fundamental mathematical skills instruction. For that reason, this historical data was deemed of import to this study.

In terms of average mathematics scores, the historical data shows that the U.S. students ranked low at the 4th grade average mathematics level. Comparatively, for calculator use in the classroom at the 4th grade level, the U.S. ranked high, in the top 3. Even though virtually all of the students in the study reported having access to calculators at home, most of the countries represented *never* use calculators at the 4th grade level. However, the U.S. students were more likely use calculator usage in 4th grade classroom. Furthermore, by the 8th grade, the United States ranked last of the 12 countries in mathematics achievement. Although this archived study may have a focus on calculator access in homes it still gives a hint of a trend that countries with increased calculator usage at the fundamental lower grade levels in mathematics may have lower scores than those who do not.

McCulloch, Kenney and Keene investigated the use of calculators with advanced placement calculus students at the high school level (2013). The research focused on math questions that were reviewed in class in a previous lecture. Students were given the opportunity to solve problems either without the use of a calculator or with the use of a calculator. Those students who solved the question without the calculator and used their own level of understanding and math skills were more likely to accurately to solve the question. However, those students who heavily used the calculator, even on the questions based on mathematics understanding, were not as likely to accurately solve the questions.

Similarly, there is a growing concern with the extensive use of the graphing calculator and its potential for misuse in math courses. They argue that if students are relying on the calculator to solve questions which require cognitive reasoning and deduction, then they are essentially misusing the calculator. The calculator is designed to perform repeated calculations more efficiently, not serve as a crutch for a lack of mathematical understanding.

In their survey study, Mao, White, Sadler, and Sonnert (2017) examined over 7000 students who enrolled in an introductory college calculus course. After this extensive study was analyzed, they argued that extensive calculator use in high school was negatively related to students' later performance in college calculus, while putting restrictions on calculator use was positively related. The authors further stated that:

> The result resonates with Burrill and Breaux's (n.d.) suggestion that, while handheld technology should routinely be a part of the learning process of mathematics, the frequency and quality of the use of calculators needs to also be taken into account. Some educators complain that students lack the basic computational and arithmetic skills needed to succeed in higher education due to calculator dependency…. Our results underscore the message that a key challenge for mathematics teachers, policy makers, and educational scholars is to figure out how to use the calculators effectively in mathematics classes while not losing sight of the many techniques and materials that have shown a more substantive impact on student learning of mathematics. (Mao, White, Sadler, & Sonnert, 2017, pp. 81–82)

There has been an increase in the use of the graphing calculator in particular, in secondary mathematics classrooms. Doerr and Zangor (2000) report that "over the past decade, secondary mathematics teachers have moved to adapt the graphing calculator into their practice," (p.144). Although technology in the classroom is more than using a graphing calculator, for many math classrooms it is one of the first steps adopted to promote advanced technology. As a result, the calculator is generally used quite often in the classroom. In many secondary classrooms, the calculator access is unlimited and students are using these tools daily, including exams, particularly if the instructor feels very comfortable with using the features of the calculator; extensive knowledge of the calculator and the features and programming options can make this tool very attractive to instructors and students alike (Starr, 2002). However, using the calculator as a tool is placing it in its proper perspective. The calculator is not appropriate for all mathematical situations. Cognitive understanding and interpretation is vital to mathematical success, with or without a calculator.

High school math instructors have observed students who did not have a solid grasp of quickly multiplying numbers. Historically students were taught “old fashioned” times tables at the elementary school level. However, “many students in the United States are not efficient in solving single-digit addition, subtraction, multiplication, and division with whole numbers and have become over reliant on calculators for basic computation,” (Leach, 2016, p. 102). Many students across the United States have demonstrated difficulty with basic math fact fluency. Mathnasium (2015) also states that “it appears that many kids lack the numerical fluency necessary to develop mastery in mathematics,” (para. 4). These basic math skills include the ability to multiply single digit numbers and use ratios. These skills are imperative when working with fractions and when factoring.

These foundational math abilities are chiefly needed and are often a basic requirement before conquering more complex problems. If students do not routinely practice these basic skills, they can deteriorate. Calculator over usage cuts the opportunities to practice and build on basic math skills. Once those skills are circumvented by excessive calculator usage over time at the high school level, students head into a rude awakening after graduation.

> 89 percent of high school math teachers think their students are ready for college-level mathematics. But only 26 percent of post-secondary teachers think the students are ready once they get there…this shortfall in mathematical preparation for college-bound students has existed for a long time, but it is being exacerbated by the increased use of technology. College-level math classes almost never use graphing calculators, while high-school classes invariably do. College professors want their students to understand abstract concepts; technology advocates claim their products help teach students such abstractions, but in practice they simply don’t. (Kakaes, 2012, para. 5 & 6)

Developmental Math Coursework

Based on just a generation ago, the number of students placing into developmental math courses, previously called remediation courses, has *increased* with the advent of technology, not decreased. While the research does not prescribe the elimination of technology, it does adhere to the philosophy of limiting its application and thinking about its appropriateness in specific coursework and on assessments.

> In today's mathematics classrooms, calculators are becoming incredibly well known and used almost daily. However, there has been a common question about the use of the calculators: Is too much exposure to calculators causing students to become dependent on them and consequently start to forget basic addition, subtraction, multiplication, and division, leading into confusion on other mathematics topics because the most basic foundation of mathematics is not there? (Rohrabaugh, 2016, p. 2)

Rohrabaugh's concerns about students using calculators repeatedly for basic functions and this overuse eroding mathematical skills is evidenced by students placing into developmental math courses.

If students continue to place into developmental math classes, they are essentially, in many cases, paying college level tuition and fees for fundamental skill level high school level coursework. The cost for paying college fees, to complete high school (or earlier) level work is higher than many students realize. Potentially, this cost is not only a great financial expense, but also a cost in time. Developmental math coursework impacts the college career of students in different ways. It is possible to initially miss the potential long-term ramifications of a poor math placement. Math, more so than many other disciplines, is designed to be taught and learned layer by layer. These layers, or prerequisites, are crucial to developing an understanding of the topics.

Before trigonometry, there is algebra and before calculus, both algebra and trigonometry are expected to be mastered. Along the same path, there is no physics until calculus I has begun, not to mention calculus II and III and other mathematics courses beyond calculus. For a high school student who may have hopes of majoring in Science, Technology, Engineering or Mathematics (STEM) fields, math placement becomes exceptionally more critical. Specific STEM majors require students to place into Calculus I, as incoming freshmen. Without this minimum requirement, students are prohibited from enrolling in other freshmen level courses within the STEM majors. The other courses in the curriculum are attached to math progression. For example, without progressing to calculus I in the previous semester, students are then prohibited from enrolling in second semester freshmen courses within their major STEM field of study. This layering of prerequisites is consistent in STEM majors. Math placement, and the continued success in subsequent math courses, is vital to students' progression in many STEM curriculums, especially the following major fields of study: information technology, computer science, physics, engineering and mathematics. If students place into a math course two classes behind where they are expected to begin, they have already hit an obstacle. In these mathematics dominant majors, there are an additional number of courses that the student will be unable to register for and therefore, the student moves further behind in their degree progression. As a result, students who are not ready for first year courses place into developmental courses and therefore wait until the next semester to take a more appropriate course, until they have met the minimum mathematics requirement.

Some STEM students place into more than one or two developmental, or prerequisite, mathematics courses. These students, who place at the lowest mathematics course, may find themselves in a quandary. There are some colleges that offer prerequisite mathematics on three tiers. The highest tier of a "developmental" or prerequisite course offering for a STEM major may be an acceptable college level mathematics course for non-STEM majors. However, while many non-STEM majors never take calculus, it is the first math course of several, for the majority of STEM disciplines. Therefore, even pre-calculus, while considered by some to be a college level math course, is not even on the curriculum sheet as a credit toward graduation for STEM majors. Therefore, if a STEM major requires three courses to reach the first course in their curriculum, the slope steepens as the student climbs toward degree progression. One of the most disheartening outcomes is if the three courses are not swiftly mastered. Then the student would essentially be required to repeat the course(s), if not successfully completed. Therefore, this would result in extending an already academically rigorous course discipline experience even further.

Developmental or prerequisite math courses administered to STEM students to prepare them for calculus are not offered without fees. Students typically pay the same tuition and fees for developmental courses as they do for courses required for graduation. With the scaffolding of the math classes, three courses easily equate to three semesters of mathematics because math classes often require them to be taken in succession and not simultaneously.

This expense is demonstrated in extending to an extra year of college at a four-year institution. If financial aid is required, there is a limit to the number of semesters that a student is eligible for financial aid (Federal Student Aid, 2012). This can directly influence the affordability of college over the course of completing a degree. If students have not solidified their mathematics foundation in the trajectory from middle school to high school, then there are already some challenges with progression in a STEM major (Ocumpaugh, et al, 2016). Furthermore, an investigation of remedial education has also been investigated by the NSF to address the low pass rate of developmental math courses (2010). More than half of the students who take developmental math courses do not pass them on their initial effort.

These are a few of the main reasons why students who are behind in mathematics may ultimately extend their college career. Developmental courses are not part of a 4-year college degree path. Since math courses are often listed in order of prerequisites, it is not only the mathematics course itself; it is how it is attached to the curriculum. Specifically, mathematics is in many cases, the gatekeeper course for future progression in the major. It often precedes not only mathematics but also chemistry and computer science courses. Therefore, a couple of developmental math courses can quickly add another year to a college student, especially one majoring in a STEM major. However, let us not focus solely on the financial implications of not meeting minimum mathematics skills at the college level. The financial implications are not the only concern.

The study is not against calculator usage, only in the over usage and misuse of calculators in learning fundamental mathematics skills. Calculators in themselves are powerful and can save time and increase the ability to solve complex problems more efficiently. Calculators also increase the accuracy of solutions exponentially. They provide these advantages with a very affordable price point.

It makes sense that high school students have struggled with college level math placement exams. These exams often prohibit calculator usage. High school students traditionally have not emphasis placed on demonstrating skills without the aid of calculator usage until they enter college. Once they enter college, students are often confronted with a new regimen of approaching mathematics. Over half of the public two and four-year college report enrolling students who require developmental courses (Butrymowicz, 2017). If the number of students taking a developmental math course after graduating from high school is an indicator of poor math skills, then it is a big concern, indeed.

Summary of Chapter II

High school students in the U.S. are performing poorly in mathematics compared to their peers in other developed and developing countries. There are cognitive domains required for students in order to be successful, and these domains include: knowing, applying and reasoning (Nixon & Barth, 2014). In order to reach the mastery level of fundamental math skills, students must be able to practice these cognitive domains to concretely apply principles to solve a myriad of different styles of questions. Differing from the U.S., in many Asian cultures, mathematics is taught with a focus on repetition, in fundamental concepts. The process of learning often starts with gaining competence in the procedure, and then through repeated practice, students gain understanding, and this type of repetition is designed to promote mastery of knowledge and skills. After many repetitions and practice, concepts are more firmly established. Then, more complex and higher order topics are added for students to problem-solve in order to cultivate a deep level of understanding of mathematical topics. However, the U.S. introduces calculator usage very early in secondary education mathematical journey compared to other countries. The early calculator introduction continues to increase in frequency and scope at the high school level. Calculator usage does not decrease at any stage during the high school process. Students require repetition to cognitively grasp new math topics and themes more fully. The calculator snips away at the opportunity for students to practice basic math skills year after year. Other countries do not use calculators at the rate of the United States. Additionally, increasing to that concern is the number of students who do not pass the developmental math course with a minimum grade of a C or higher, on the first attempt (Fong, Melguizo, & Prather, 2015).

CHAPTER 3: METHODS

Research Design

A mixed methods research design is employed for this study. Many studies have reported U.S. students' low achievements in mathematics compared to other countries (DeSilver, 2017). Yet, very few studies have focused on the effect of calculator over usage on the fundamental mathematics skills of middle and high school students. Neither qualitative nor quantitative evaluation alone can provide a complete analysis of the research problem. Therefore, in order to gain more practical background, see the calculator over usage from different angles and to more fully consider objective feasible solutions, the study required both quantitative and qualitative investigations to converge (Bryman, 2006).

For this reason, this study employs a concurrent-independent mixed methods research approach (Schoonenboom & Johnson, 2017), particularly the convergent parallel design. In the convergent parallel design, both the qualitative portion of the study and the quantitative portion of the study have equivalent weight. Furthermore, this study is not limited to merely exposing one major factor in the decline in math achievement. Rather, it is designed to create some opportunities for closing the gap with actual practical, expedient and sustainable resolutions. The intrinsic rigor of the study, therefore, necessitated a more intense and focused scrutiny of the diverse aspects of the over usage of the calculator.

The purpose of this study is twofold (See Figure 2). First, this study quantitatively examines calculator usage effects in secondary education by comparing the fundamental mathematics skills of 8^{th} and 12^{th} grade students. In this quantitative strand, this study seeks to determine the difference, if any, between the fundamental mathematical skills of the two grade level groups as a result of the increased calculator usage at the high school, which may impact limited opportunity for repeated math practice, in the form of extensive fundamental math skills repetition. In the quantitative strand, this study examines calculator usage effects in secondary education by hypothesizing that the increased calculator usage in current secondary mathematics classrooms negatively affect students' fundamental mathematics skills. Two grade level groups (8^{th} and 12^{th} graders) are selected to statistically examine the effects of calculator usage. For quantitative data, the mathematics assessment (FMSA) will be employed to determine the fundamental math skills of participating students and to gauge if those skills are changed through 12^{th} grade. In the qualitative strand, this study explores students' and teachers' perception on calculator usage in the classroom and their learning and teaching experiences of mathematics, respectively. Semi-structured interviews will be conducted in a face to face format for the schoolteachers. Furthermore, each interview will be audio recorded and will be transcribed.

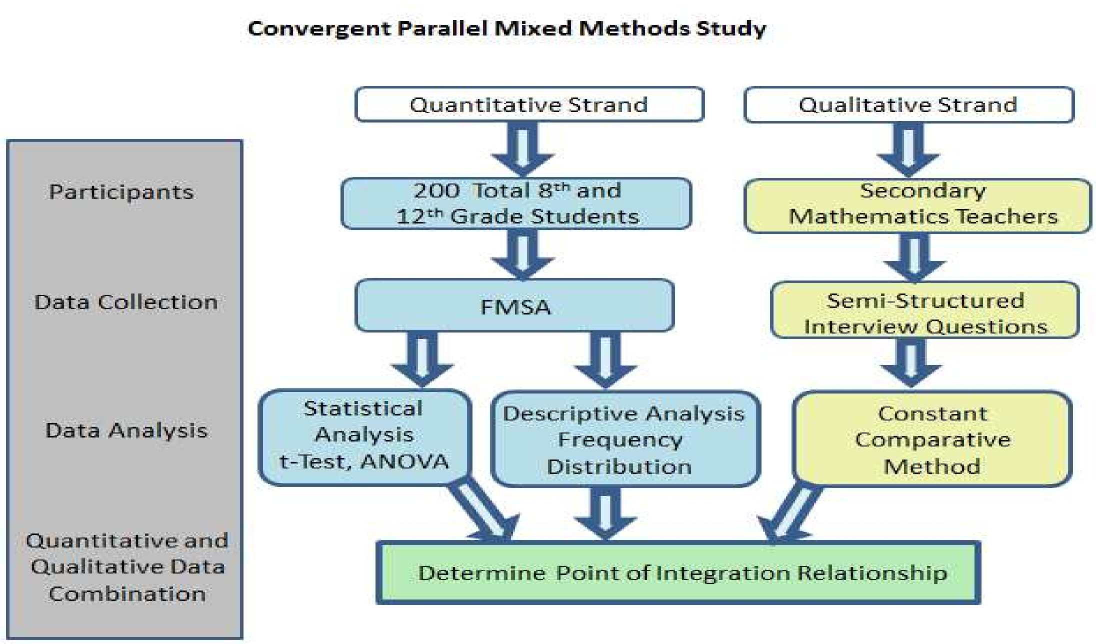

Figure 2. Flow of Research Design for this Convergent Mixed Methods Study.

Participants

Participants for this study include 8th and 12th grade students, and secondary school mathematics teachers. The plan is to have at least 100 student participants in 8th grade and at least 100 student participants in 12th grade for a total of 200 student participants. The mathematics teacher participants will total five to seven across the secondary school platforms. For the quantitative strand, each student participant will be selected from local middle schools and high schools. The 8th graders were chosen to be participants in this study since most students in the United States are placed into a solidified math track by the 8th grade. According to the Common Core State Standards, there are skills that students are expected to be proficient in by the 8th grade level (Delaware Department of Education, 2017). These critical fundamental math skills serve as the foundation and travel with a student for the lifetime of their mathematical journey. Furthermore, these abilities unlock the key to obtaining proficiency in future math courses and lacking them makes proficiency in future math courses increasingly challenging. McKibben (2009) also argues “without first mastering the basic skills, students can’t grasp the complex nature of algebra, let alone algebra’s successors” (p. 63).

In addition to the 8th grade, the students who are in their senior year of high school were also purposefully chosen for this study. Seniors have had several years of math courses and have had extensive and widespread calculator usage throughout the last four years of high school (Robelen, 2013). Seniors take standardized exams to be eligible for college credit once they enter college (College Board, 2017). U.S. high school students are required to take years of mathematics, according to their state, to be eligible for high school graduation (Education Commission of the States, 2017). Therefore, presumably 12th grade student math skills will be at the highest of their career at the senior level of high school. By this time, their level of math skills is expected to exceed the fundamental basic level. Seniors are expected to have built upon this elementary level to a more advanced capability and their basic math fact fluency is presumed to be automatically ingrained. Therefore, if 12th grade students do not perform as well on this basic math assessment as the 8th grade students, it will alert the researcher that fundamental mathematics skills may indeed be deteriorating at the high school level.

Participants will be traditional 8th grade or 12th grade students in public, charter or private schools within the northeast region of the United States. The participants will take the assessment and survey, while being proctored by the researcher. Participants will answer all questions on site and the researcher will gather the results. The younger students will typically range in age from 13 to 14 years of age, while in the 8th grade. They will likely be in middle school or junior high school depending on the county of residence. Older students will typically range in age from 17 to 18 years of age, while in the senior year of high school. Students participating in the research could be from academically strong school districts or from districts needing improvement. Socioeconomic status may be thriving or limited. Regardless of background or familial status, all of the student participants will have the same assessment, and demographic information of participants will be reported.

Furthermore, students will be recruited from traditional public school mathematics courses at their local middle or high school. The students will ideally primarily come from traditional mathematics classes. The goal is to focus on classes that are not honors or advanced, nor classes requiring increased supplemental resources, unless these classes are balanced out so that there is an equitable pairing. The principal investigator will proctor the assessment and the survey. In addition, the relationships with school principals, teachers and other administrative facilitators, supporting this initiative, will offer added opportunities to meet with students. After school programs showed initial interest in support of the study and offered access with principal permission. However, the principal investigator's committee advised a focus on the traditional classroom as the sole focus of student participants. Therefore, the investigator focused all efforts on gaining classroom access directly through the principal of the school and subsequently with teacher participation and support. The principals showed the greatest resource in terms of working with the investigator to permit access to students and permit the assessment and survey to take place at their school, only after IRB permission is obtained. University support was initially an option as a second route to obtain 12^{th} grade students participants, in particular. During campus tours, students have been informed of the study and willing participants could then choose to participate in the assessment and then share their experience with calculator usage in the survey. Again, this would occur only after IRB approval was granted. Ultimately, the direct classroom visits will be the primary goal for obtaining enough participants for the study, in its entirety. Each grade level would be administered the exact same assessment.

For the qualitative strand, six teachers from local middle and high schools will be purposefully selected. The 8^{th} graders teachers would be selected from the participating middle schools and teachers who instruct 12^{h} grade students would also be selected from the participating high schools. The teachers who instruct 8^{th} and 12^{th} grade students in mathematics would be asked the same semi-structured interview questions. This purposeful sampling of teachers is important to the focus of this study (Palinkas, Horwitz, Green, Wisdom, Duan, & Hoagwood, 2015). Teachers are exceptionally knowledgeable of the advances and challenges students face and teachers have the background on how and why calculator usage has been incorporated in the American classroom. The middle school and high school teachers are the ones who see the results of years of schooling before students enter their classes. Teachers have the unique ability of being able to adjust a lesson in the middle of instruction, as they deem necessary. The difference between the planning and the enactment of subject matter is often directly related to student concept understanding. This is true not only for both 8th and 12th grade secondary educators. The actual student reactions and the practical solutions and or concessions made in the classrooms are what the study plans to explore in the semi-structured interview.

Data Collection

The Fundamental Mathematics Skills Assessment (FMSA) will be employed for collecting quantitative data from students and a semi-structured interview will be conducted to collect qualitative data from mathematics teachers for this study. The principal investigator with proctor the assessments and conduct the interviews.

Fundamental Mathematical Skills Assessment

For quantitative data, 8th and 12th grade students' scores on the Fundamental Mathematical Skills Assessment (FMSA) will be collected. The FMSA is a conventional standardized test, and the questions on FMSA were developed based on the Common Core State Standards of mathematical concepts students should know up to 7th grade, including: multiplication, division, estimation, place value, understanding of operations with fractions, solving of proportional and real-world mathematical problems using algebraic expressions, analyze and solve linear equations and work with radical and integer exponents (Common Core State Standards, 2017, p.2). The questions for this study were selected from a bank of typical mathematics questions vetted by the local regional State University Testing Center, which are originally from ACCUPLACER, for which reliability and validity is already established.

> ACCUPLACER is an integrated system of computer-adaptive assessments designed to evaluate students' skills in reading, writing, and mathematics. For over 30 years, ACCUPLACER has been used successfully to assess student preparedness for introductory credit-bearing college courses. ACCUPLACER delivers immediate and precise results, offering both placement and diagnostic tests, to support intervention and help answer the challenges of accurate placement and remediation. (The College Board, 2018, para. 1)

The FMSA provided to both 8th and 12th grade students is designed to determine the fundamental math skills of students and to identify whether the increase in calculator usage at the high school level impacts their fundamental math skills. There is an ongoing debate on whether calculator usage has a negative effect on math skills (Starr, 2002). Therefore, this study will analyze students' scores on FMSA to examine a possible relationship between calculator usage and fundamental math skills.

The FMSA has two parts. First, it has 22 math questions. The first 10 questions of the Fundamental Mathematical Skills Assessment are designed to ascertain the proficiency in the following content areas: operations with whole numbers, applications and problem solving, operations with decimals and percents, and finally operations with whole numbers and fractions including: multiplication, addition, subtraction, decimals, percent and estimation. The second set are Questions 11 – 22, which will specifically address the ability to perform elementary algebra in terms of numbers and quantities, perform algebraic expressions and problem solving, work with equations and inequalities and determine the ability of students to simplify algebraic expressions, as well as use a grid as a coordinate axes to plot points. All of the questions are selected with the consideration of the 8th grade students' math progression and the material that they have covered in class, based on the common core state standards for U.S. students. There is a distinct sequence of topics that are leading to algebra and more advanced math coursework in the outline for students from kindergarten through 7th grade. This foundation is developed to provide math skills and problem-solving abilities to promote proficiency in math for years to come. Each mathematical year builds on the topics of the previous year.

In addition to math questions, the FMSA contains a survey, asking students' perception on calculator usage in a math classroom, and their learning experience in learning of mathematics. The survey consists of three main areas with a total of 12 questions. The first component looks at access to calculators and if they are provided in the classroom. Secondly, the study asks specifically if students use calculators on exams. Thirdly, there is a short answer question on why students feel that they need a calculator for their coursework. In addition, the survey asks students to identify their perception of the instructional environment in the classroom. Finally, demographic data is also obtained in the survey.

A four-level Likert scale will be used in which students will identify if they Strongly Agree, Agree, Disagree or Strongly Disagree with prompts about calculator access and usage. This four-level scale helps to find the students' perception on their experience and to avoid neutral non-noncommittal responses. "Likert-type scales are one of the most commonly used psychometric scales for examining self-reported perceptions and attitudes. It is a unidimensional scaling approach based on classical measurement theory, which uses a single type of stimulus and a single type of response," (Ho, 2016, p.676).

The survey method is designed to take data from a sample and extrapolate information, trends and new uncharted testimony, which can later be used to corroborate theories, substantiate effects, as well as invalidate hypotheses and challenge hearsay. "Survey research can be very powerful and may well be the only way to conduct a particular inquiry or ongoing body of research," (Draugalis, Coons, & Plaza, 2008, p. 1). These researchers also firmly believe that a survey conducted in a methodical fashion with carefully constructed research questions can have rich contribution to literature, especially when the investigator invests the effort to industriously craft a pilot of the study before its launch. This survey method will help "to examine a situation by describing important factors associated with that situation, such as demographic, socio-economic, and health characteristics, events, behaviors, attitudes, experiences, and knowledge," (Kelley, Clark, Brown, & Sitzia, 2003, para. 4). Therefore, this survey is crafted to gather information to begin to identify students who consistently use calculators and compare their assessment scores to those who do not consistently use calculators. The validity and the reliability of the survey will be established by first assessing the students' frequency of calculator usage and then the extent of use in terms of whether or not the calculator is used on exams. Also the survey questions are logically scaffolded to gain a greater depth of knowledge of the perceptions and practices of students. Furthermore the survey has been piloted with a group of students to determine the appropriate approximate time allotment for the survey and to address the clarity of the questions. The piloting of the assessment has resulted in eliminating questions that were too long or unclear and adding a question to complete the covering of topics.

Semi-Structured Interview

The semi structured interview will be conducted to collect qualitative data. The semi-structured interview is a methodology for gathering data in a qualitative format in which open ended the questions are securely asked by the interviewer; however, there is the opportunity for follow-up questions and room for the interviewee to give additional background and other participants to have the opportunity to have discussion. The semi-structured interview is used extensively in qualitative research in large part as it lends itself equally well in individual and in group settings to obtain rich qualitative data (Jamshed, 2014). In this study the semi-structured interviews will take place in a face to face audio recorded format. Some of the benefits of the face to face format of a semi-structured interview include: discuss questions in a comfortable setting, the ability to observe body language, non-verbal cues and small sounds, determine and assess small nuances of silence in the response and discussion, discern interest and attention, and control the timespan of the interview (Irvine, Drew, & Sainsbury, 2012) . This interview method will give a voice to participating teachers' concerns, expectations and plans as well as potential frustrations, solutions and opportunities for improvement. The intent of the interviewer is to guard against bias and to focus on gathering data in a way that fosters openness and candid dialogue between the interviewer and the interviewee (Diefenbach, 2009). As the front line of the educational system, teachers have a unique position as they provide instruction as well as complete requirements from educational leaders at a local and district level. This study seeks to determine how they witness student fundamental mathematics skills (or the lack thereof) and how they address these issues in their individual classrooms. Since a teachers' confidence level has a direct impact on students, one of the semi-structured interview questions will also focus on the level of confidence in math instruction. Research indicates that teachers' confidence in their personal math abilities exerts a measurable influence on children's math attitudes (Chen, McCray, Adams, & Leow, 2014). For this reason the semi-structured teacher interviews will include 8th grade instructors and 12th grade instructors. The study will consist of a total of five to seven mathematics teachers. The face to face semi-structured interviews for teachers are planned within a peaceful, comfortable and relaxed atmosphere that will facilitate discussion without disruption.

Based on the reviewed literature of teachers' perceptions on calculator usage, and their differing views surrounding support for and concerns against levels of calculator usage, the interview questions were carefully crafted to address key concepts in determining the insights of teachers and calculator usage in their classrooms. These interview questions were additionally vetted, after several discussions with faculty in the field of education, to purposefully align the semi-structured interview questions with the student survey for a more thorough data analysis. Furthermore, this study intentionally employed mixed methods to triangulate qualitative and quantitative data, for a more comprehensive and robust study.

The questions for the teachers will focus specifically on how the use of calculators plays a role in their class. The interviewer will determine if the calculators are permitted in classwork only or whether they are also allowed on exams. The parameter of calculator usage will be expressly asked. Discussion surrounding the background of how each teacher came to teach mathematics is also a vital aspect of this study. Some teachers find themselves teaching mathematics courses even if that was not the original intent of their teaching path. The interviewer seeks to expressly clarify that information. It is deemed important because the teachers' confidence level does affect students (Chen, McCray, Adams, & Leow, 2014). Furthermore these questions have been piloted to determine the clarity of the questions. As a result of piloting, the semi structured interview questions have been revised and updated. The wording is streamlined and the questions that were too long or unclear have been adjusted. In addition, the definition of fundamental mathematical skills has been added for additional clarity.

Mixed Method Instrument Validity and Reliability

"The mixed method approaches have recently risen to prominence. The reason that more researchers are opting for these types of research is that both the qualitative and quantitative data are simultaneously collected, analyzed and interpreted," (Zohrabi, 2013, p.254). This study is employing several different sources and strategies in order to extract how calculator over usage may affect student learning of fundamental mathematical skills. Both quantitative and quantitative strands will be conducted simultaneously to offer greater substance, depth and breadth to this investigation. The research instruments include a quantitative fundamental mathematical skills assessment (FMSA) which will be proctored and assessed at the school location with the same maximum time, for each student, to promote and establish internal reliability. The qualitative semi-structured interview questions for professional mathematics instructors is designed to measure behaviors and practices and to corroborate and confirm experiences and perceptions to authenticate content validity. The goal is for each instrument is to measure what it is intended to measure,(maintain reliability) and the goal of this study is to provide instruments that are accurate, (or valid).

The purpose of the semi-structured interview questions is to discover the perceptions of teachers in regards to calculator usage and potential calculator over usage and how the calculator impacts students' learning of fundamental mathematical skills in their classrooms. These interviews are designed to offer the investigator a chance to freely discuss concerns with professional mathematics teachers in a comfortable and unrestricted environment. The study seeks to determine, via semi structured interview responses from teachers, if there is conspicuous commonality of perceptions and experiences. The teachers will be from differing schools in differing grade levels and the study will record if they are saying the same things across their public education sphere. This will determine a degree of reliability. The study will discover if students who are in college prep mathematics classes in high school are experiencing the same challenges that middle school students experience in introductory algebra or geometry classes. These results will display another potential degree of reliability. If there are specific topics that all students struggle with in the FMSA, that will be revealed as well. The triangulation of the instrument results and responses will strengthen the overall reliability of the study, particularly if the mathematical topics and concerns that teachers express in their classrooms are confirmed with the student data results of the FMSA.

According to Leung, if the "research question is valid for the desired outcome, the choice of methodology is appropriate for answering the research question, the design is valid for the methodology, the sampling and data analysis is appropriate", then the results and conclusions should be valid for the study (2015, p. 325). The research questions for this study are specifically associated and aligned with the FMSA for students and the semi structured interview questions are tied and aligned for responses from teachers to more fully answer the research questions.

Data Analysis

Quantitative Data Analysis

Quantitative data will be analyzed by using SPSS statistical software to determine if there is a statistically significant difference between understanding of fundamental mathematical skills for 8th graders and for 12 graders. After the results of the results of the test are gathered, the data will be used to determine if a correlation exists between increased calculator usage and a decrease in fundamental mathematical skills.

The study plans to use statistical software designed to analyze the data in two phases. The first phase will incorporate a t-Test and the second phase will incorporate an analysis of variance (ANOVA). The t-Test is planned for the 8th and 12th grades students who are administered the fundamental mathematical skills assessment. The means of their scores will be compared to see if there exists a statistically significant difference between these two groups. An analysis of variance (ANOVA) test will be used in the fundamental mathematical skills survey of calculator usage in order to more deeply compare multiple groups. The groups by grades will further split depending upon their accessibility and usage of calculator in a classroom. Therefore, the four groups for the ANOVA will consist of: 8^{th} grade students with virtually unlimited calculator usage, 8^{th} graders with reduced calculator usage, 12^{th} grade students with virtually unlimited calculator usage, and finally, 12^{th} graders with reduced calculator usage. This will provide an opportunity to look at the data and determine which group has stronger mathematical skills or if there is not difference. The null hypothesis for the quantitative strand of this study is that there is no significant difference between four groups in terms of their scores on the FMSA. These two parts of the research design will provide data to analyze each group and determine valid and reliable results based on the t-Test and the ANOVA. P-values are not the only determining factor of significance in a robust analysis (Sullivan & Feinn, 2012). Student perceptions, experiences and practices will also be investigated. The ramifications and the potential magnitude of the findings will also be analyzed in the results section of the dissertation.

Qualitative Data Analysis

The qualitative data will be harvested from the semi structured interview responses from mathematics teachers. Each response will be recorded and transcribed. Notes will be made to help organize the responses and the transcripts will be carefully read and reread for the initial words and phrases that accompany the responses. The pertinent and significant words and phrases will be isolated for further review. The plan of the study is to assess, in an unbiased format, the important and applicable repeated comments and phrases from the interviewees. They will then be assigned a significant label. These labels and codes may be significant and numerous and the job of the investigator is to code or group similar categories or themes. By creating the categories and the themes the research becomes more focused and deliberate. The themes that emerge may be expected to some degree, however this investigation is ready for the discovery of the unexpected. The creative interaction between themes may result in some surprising results and develop future conclusions or areas for future study.

The themes that develop will be identified and coded, in the study. They will be based on Constant Comparative Methods (CCM) of grounded theory. This method of coding was distinctly selected in order to analyze the quantitative data gathered from the mathematics educators. CCM closely aligned with the researcher's goal of obtaining the perception of the teachers and using interviews to compare their experiences with calculator usage in the classroom. "By comparing, the researcher is able to do what is necessary to develop a theory more or less inductively, namely categorizing, coding, delineating categories and connecting them. Constant comparison goes hand in hand with theoretical sampling," (Boeiji, 2002). CCM of grounded theory is successfully incorporated with individual examiners as well as with multiple investigators to identify common categories and highlight interconnecting ideas (Olson, McAllister, Grinnell, Walters, & Appunn, 2016).

The first category is student Calculator Access and Usage in the classroom. This category is coded as CAU. This category is a review of whether or not students have access to calculators and how often they use calculators in the classroom as they are learning and assessed in mathematics. The second category is student Mathematics Abilities and Practice. The second category is coded as MAP. This category looks at how teachers perceive the mathematical ability of their students and their fundamental skills without a calculator and how students practice their fundamental mathematics skills and how they acquired these skills. Mathematics skills require practice. However, by the usage of calculators at the high school, and often middle school level, students may not be practicing fundamental mathematics skills. If students know there is essentially no limit to calculator usage, areas in which students lack skills may be overlooked.

Qualitative analysis is vital to this study in order to gather information about calculator usage and how prevalent it is in the classroom. These expressions and responses are coded, or identified and linked into a specific category. The categories, or groupings, are then analyzed. As a result of the analysis, evaluations can be made and patterns determined. In this study, there are some results that may not be unanticipated; however, the opportunity to explore new ideas and discoveries is exciting.

Mixing Quantitative Results and Qualitative Findings

The semi-structure interview and survey items in the FMSA are designed to corroborate with the Quantitative assessment administered to the same 8th and 12th grade students. The study will thoroughly seek to find out if the scores of students who self-identify that they do use calculators on coursework in class and on exams have statistically higher or lower scores than students who self-identify that they do not use calculators during classwork or they do not use calculators on exams. Furthermore, a semi-structured interview shares teachers' perceptions on calculators as well as their teaching and learning experiences of mathematics learning. Survey items in the FMSA ask students' perceptions on calculator usages and their learning experiences in math classrooms. Any relationships between the FMSA and the teacher interview responses and teacher perceptions on student achievement strengths, or student achievement weaknesses, will be emphasized.

Potential Ethical Issues

Institutional Review Board (IRB) approval is needed before the researcher would be permitted to assess students with a math test or with a survey. The IRB approval is also required to ask mathematics teachers the semi-structured interview questions. Once approval is granted, the researcher plans to begin to gather data from students. In this study, the instrument is a fundamental math assessment and a survey of calculator usage. Each of these two parts of the instrument is focused solely on the ability to perform basic math facts as outlined by the CCSS and the investigation of calculator usage in U.S. classrooms. Other than obtaining IRB approval, there are no anticipated ethical issues involved in the administering of the math assessment or in the survey questions for this research. The students would be advised that participation in the assessment is voluntary. Each of the students would have the freedom to decide and choose whether or not to participate in the study.

In the data collection, the students will complete the assessments at local high schools as well as at local after-school programs for the middle school students. The teacher semi-structured interviews will occur in a relaxed environment that will enable the interview to occur without disruption. Relationships have been developed with the examiner and local school districts and principals in order to obtain data. This interaction with the schools and the administration helps to pave the way for access to assess students and mathematics teachers.

Summary of Chapter III

This mixed methods research employs the convergent parallel design. In the quantitative strand, this study examines calculator usage effects in secondary education by hypothesizing that the increased calculator usage, in current secondary mathematics classrooms, affect students' fundamental mathematics skills. Two grade level groups (8^{th} and 12^{th} graders) are selected to statistically examine the effects of calculator usage. For quantitative data, the mathematics assessment (FMSA) will be employed to determine the fundamental math skills of participating students and to gauge if those skills are changed through 12^{th} grade. Quantitative data will be analyzed by using SPSS statistical software, particularly t-Test and ANOVA, to determine if there is a statistically significant difference between understanding of fundamental mathematical skills for 8^{th} graders and for 12 graders. In the qualitative strand, this study explores teachers' perception on calculator usage in the classroom and their teaching and learning experiences of mathematics. Semi-structured interviews will be conducted face to face, and audio recorded, and all interviews will be transcribed. To mix quantitative results and qualitative findings, the survey items in the FMSA, asking students' perceptions on calculator usages, and their learning experiences in math classrooms serve a bridge between two strands. Any relationships between the interview responses and the teacher perceptions on student achievement strengths or student achievement weaknesses will be emphasized.

CHAPTER 4: FINDINGS

The purpose of this mixed methods study has two parts: a quantitative examination of student fundamental mathematics skills and a qualitative investigation of teacher perceptions on calculator usage in the classroom. The hypothesis for the quantitative strand was that there is no significant difference between 8th and 12th graders' scores on the FMSA when assessed without the use of a calculator. This hypothesis stemmed in response to the widespread observation of calculator usage at the high school level. According to Sweller (1994), the mastery of any specific topic would require not only acquiring those skills but making those skills "automatic" (p. 296). In other words, students need to practice in order to reinforce fundamental mathematics facts. Students benefit when they learn new skills and practice them. New skills become old skills after reinforcement and practice. Basic fundamental mathematics skills can become ingrained to the point that processing these skills becomes a basic automatic process. Automatic skills are not easily forgotten. Therefore, the limited instruction time with the practice of fundamental mathematics skills, due to over usages of calculators, might negatively impact students' fundamental mathematics skills. The qualitative strand is focused on teachers' perceptions and practice on calculator usage in the secondary schools. Schoolteachers work with students at varied skills levels and abilities. Their observations and experiences in instruction have a great impact on student learning. The opinions of the teachers can also affect teaching styles and the atmosphere in the classroom. For these reasons, teachers were equally important in this mixed method study

are presented in order, starting with the quantitative strand first and the qualitative strand second. Then, both the quantitative results and qualitative findings are compared and contrasted. These observations may then become more concrete in terms of how they point to a similar concept or conclusion. Through the cross referencing of similar topics, from a series of different perspectives, quantitative results and qualitative can then be further triangulated.

Quantitative Results: Secondary Student Fundamental Mathematics Skills

Descriptive Statistics

327 students, in total, were assessed on their fundamental mathematics skills. A total of 22 mathematics questions were asked on the assessment. The highest potential Sum Correct was 22. Students who chose not to complete the quantitative Fundamental Mathematical Skills Assessment were discretely excluded from the study in order to limit the skewing of the data. These assessments, which were not completed, or contained excessive blanks instead of responses, were gathered with all of the other students. However, they were not incorporated in the gathering of mean data collection. As a result, there were a total of 303 students who ultimately comprised the data gathered for quantitative analysis.

Data analysis indicated that the 8th grade students scored higher overall than the 12th grade students. The 8th grade students had a higher mean score that the 12th grade students. The 8th grade students also had a higher median score than the 12th grade students. The students in the 12th grade math course exceeded the 8th graders in the mode score. Each of the grades had a very similar standard deviation separated by less than one eighth of a point. This initial preliminary analysis was shared with each of the six schoolteachers for the qualitative strand. Table 2, below, provides a snapshot of the initial descriptive statistics of the students in both grades:

Table 2

8th and 12th Grade Descriptive Statistics

		N	Mean	Std. Deviation	Std. Error Mean
Average Score	8th	194	59.61	18.68	1.341
	12th	109	53.75	18.15	1.74
Sum Correct	8th	194	13.08	4.193	.301
	12th	109	11.83	3.993	.382

Comparison of 8th and 12th Grade Students' Fundamental Mathematics Skills

A test for normalcy.

8th and 12th grade students' scores on the FMSA were compared, see Table 2. To compare mean scores of two groups, a test for normalcy was conducted to determine if the data were normalized. If data follow a normal distribution, the data are symmetrical about the mean. If the normalized data are graphed in a histogram, there is a symmetrical display of data which imitates the shape of a bell, hence the "bell curve" terminology. For the 12th grade students, the data are normalized and the null hypothesis is not rejected. The Shapiro-Wilk test of significance is 0.256, which is above 0.05 and therefore there is not a statistically significant difference between the 12th grade student scores and a normal distribution of data, see Table 3 and Figures 3 and 4. Therefore, there is a normal distribution of data for the 12th grade students. The Shapiro-Wilk test is more rigorous than the more antiquated Kolmogorov-Smirnov test, however, both results are typically reviewed in a test of normality, (Ghasemi & Zahediasl, 2012).

Table 3

Tests of Normality12th Grade

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Sum Correct	.074	109	.175	.985	109	.256
Average Score 12th Grade	.074	109	.175	.985	109	.256

a. Lilliefors Significance Correction

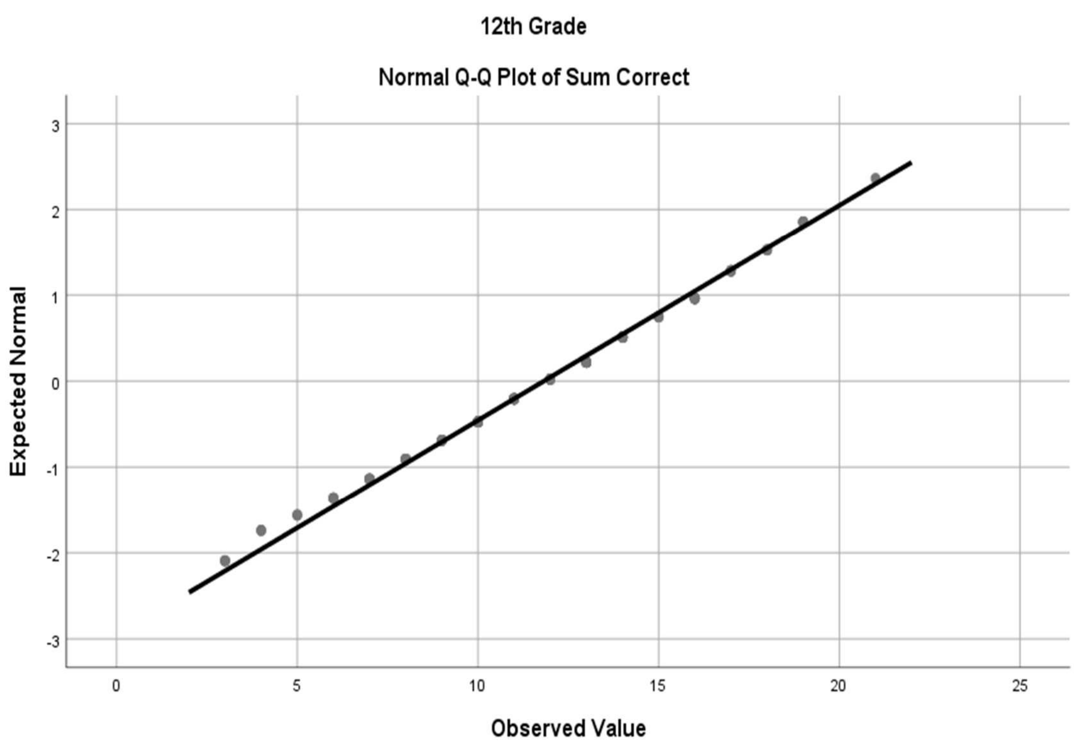

Figure 3. 12th Grade Q-Q plot.

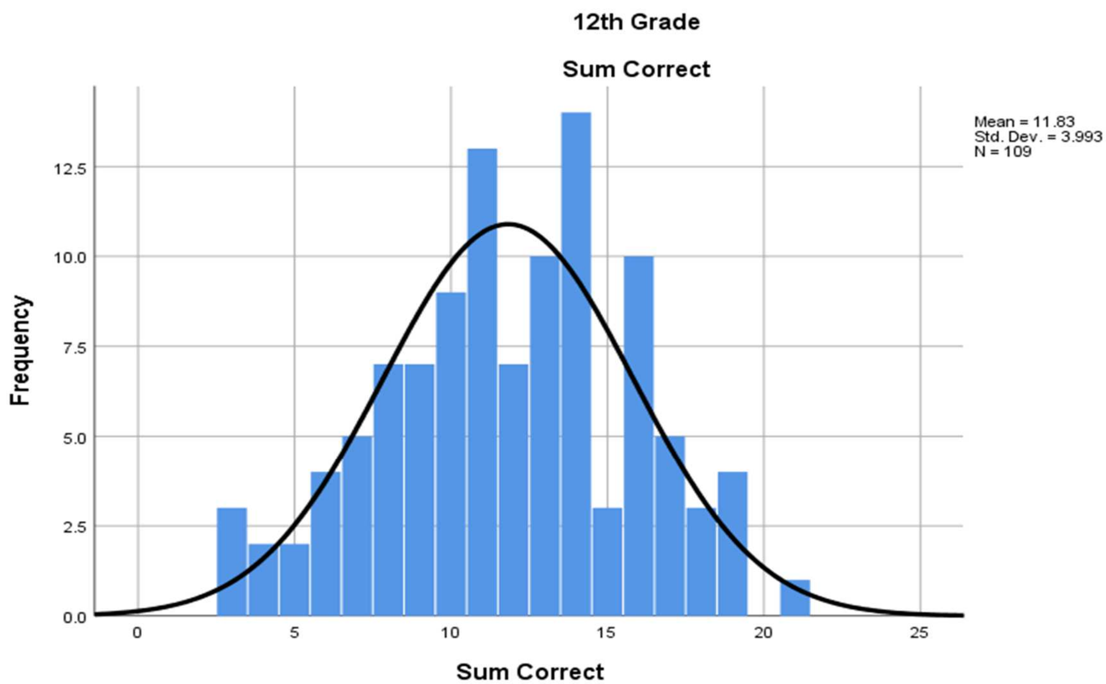

Figure 4. 12th Grade histogram and normalized curve.

Data often have values that go above or below a perfectly normal distribution. In the case of the 8th grade students, there were more students assessed than those in the 12th grade mathematics course. Coupled with the frequency of those scores, particularly the high frequency sum of 11 correct, and the higher number of students assessed at this grade level, the data did not fit a perfectly normal distribution for the 8th grade, see Table 4.

Table 4

Tests of Normality 8th Grade

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Sum Correct	.074	194	.012	.981	194	.009
Average Score	.074	194	.012	.981	194	.009

a. Lilliefors Significance Correction

In goodness of fit parametric test analysis, the limitations include the approximation of data aligning to fit a perfectly symmetrical group of values. Coin's (2008) study found the following:

> A problem common to most of these tests is sensitivity to the presence of outliers in the sample. In fact, a single such observation can lead to rejecting the null hypothesis even if the majority of the data are drawn from a normal distribution. (p. 4)

Data that is not perfectly normal and approximates a normal distribution may be skewed to the left or to the right, (Krithikadatta, 2014). That is the case of the 8th grade student data. As a result, a closer look was observed with the skewness to determine if there was a z value between -1.96 and 1.96, which is said to have a normal distribution. In the case of the 8th grade students, the z value is indeed between these parameters based on the Descriptive Analysis for Skewness of 8th Graders Table. In this case, the skewness statistics divided by the standard error skewness results in a skewness z-score of -0.8. This lies within the parameters of a normal distribution z-score of > 1.96 or < -1.96, see Table 5.

Table 5

Descriptive Analysis for Skewness of 8th Graders

			Statistic	Std. Error
Sum Correct	Mean		13.11	.295
	95% Confidence Interval for Mean	Lower Bound	12.53	
		Upper Bound	13.70	
	5% Trimmed Mean		13.14	
	Median		13.00	
	Variance		16.889	
	Std. Deviation		4.110	
	Minimum		3	
	Maximum		21	
	Range		18	
	Interquartile Range		5	
	Skewness		-.14	.18
	Kurtosis		-.65	.35

In this case, the skewness statistics divided by the standard error skewness results in a skewness z-score of -0.8. This lies within the parameters of a normal distribution z-score of > 1.96 or < -1.96.

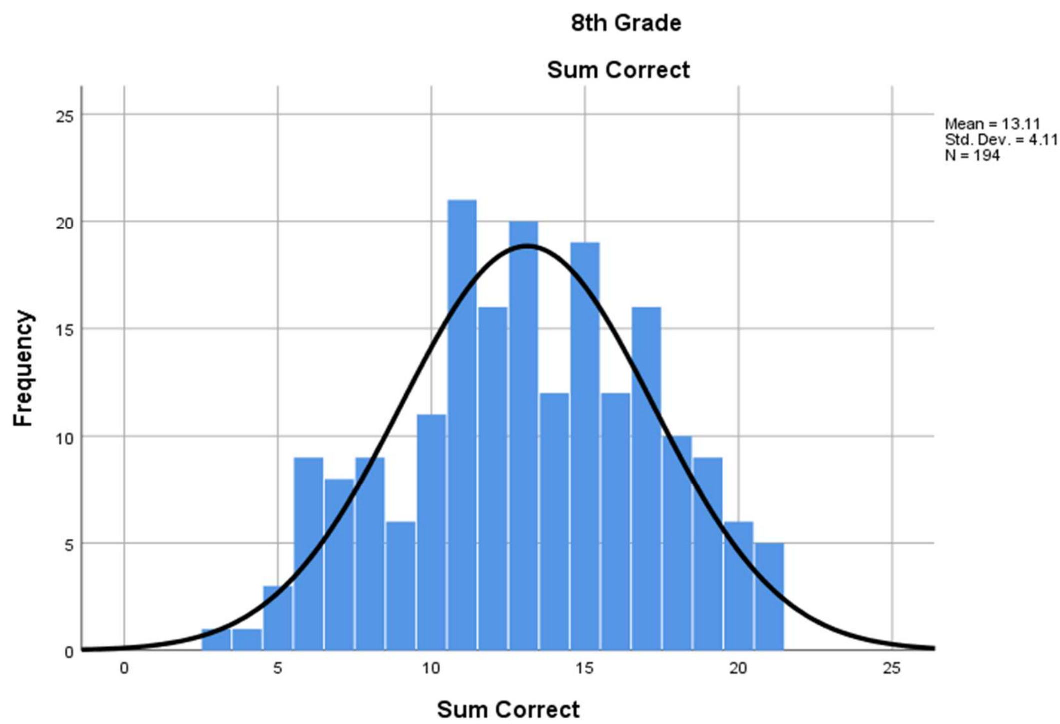

Figure 5. 8th Grade histogram and normalized curve.

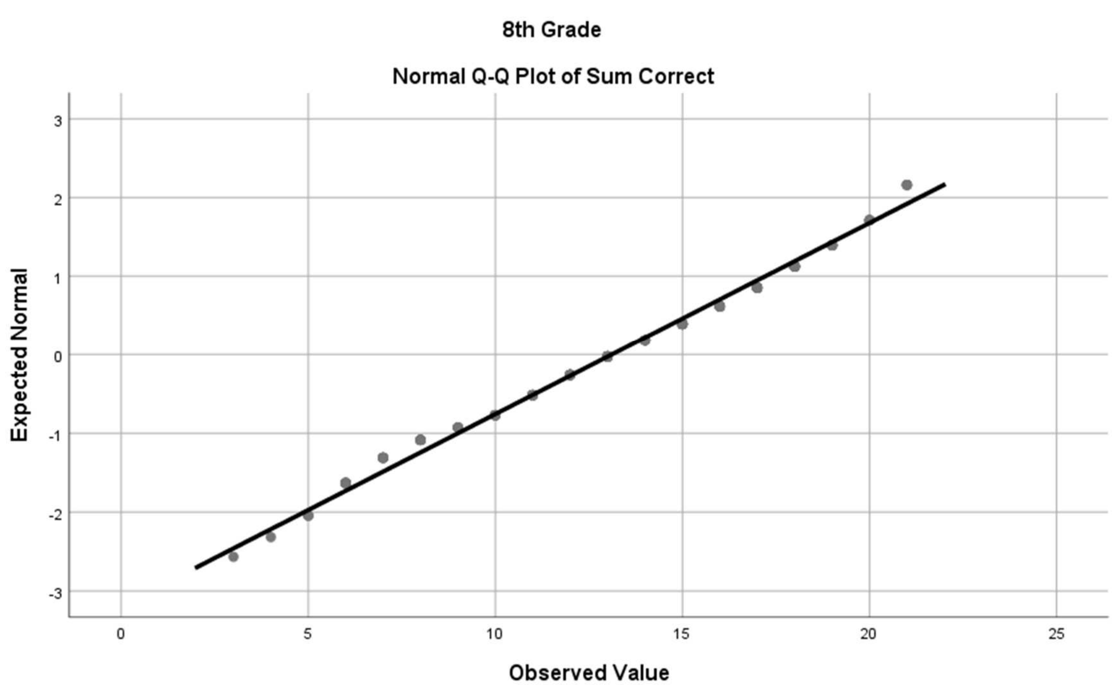

Figure 6. 8th grade Q-Q plot.

Based on the histogram with the normalized curve in Figure 5, the normalized standard error skewness z-score of -0.8, the normalized Q-Q plot in Figure 6 and the sample size of N=194 as well as other statistical findings, we will not reject the null Hypothesis based on all the visual and statistical factors that point to a normal distribution of data. Therefore, we can still use parametric As a result, the research proceeded with an independent sample t-Test to compare the scores of 8th and 12th grade students.

Independent sample t-Test.

Independent sample t-test was conducted to compare 8th and 12th grade students' scores on the FMSA, see Table 6. The null hypothesis for the present study was there is no significant difference between 8th and 12th graders' scores on the FMSA when assessed without the use of a calculator.

This hypothesis was founded on the philosophy that presumed because of the extensive calculator usage by the time students were in12th grade, there fundamental mathematics skills may be potentially eroded. This presumed erosion would limit their ability to significantly surpass the 8th graders without a calculator.

However, based on the comparison results between the means of the 8th and 12th grade students, there *is* a statistically significant difference between the 8th grade students' average score and the 12th Grade students' average score on the fundamental mathematical skills assessment, as assessed without a calculator in this study. The Independent sample t-Test reports the level of significance. If the generated level of significance is less than 0.05 there is a statistically significant difference between the two values. The significance for the 2-tailed t-Test is 0.012 which is less than 0.05, see Table 6. The 8th graders outperformed the 12th graders in overall mean, as well as a higher median score.

Table 6

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Sum Correct	Equal variances assumed	.260	.611	-2.5	301	.012	-1.25	.49	-2.22	-.281
	Equal variances not assumed			-2.6	233.22	.011	-1.25	.48	-2.21	-.293

Student Responses to Survey: Student Perceptions on Calculator Usages and Access to Calculators in Learning of Mathematics

In the FMSA, students were asked to respond to questions pertaining to gender, ethnicity, age, the current math class they were enrolled in and the state location of their middle or high school. Questions 23 and 24 inquire about a students' grade level and age, respectively. The age range of students encompassed 12 to 19 for grades 8 and 12. For a full detail of question 28, there are several differences between math courses for 8^{th} graders and 12^{th} graders. There were a total of fourteen classes assessed from three different schools. The 8^{th} graders comprised eight of the fourteen classes and the 12^{th} graders consisted of six different classes. There were two algebra classes within the 8^{th} grade math courses; the other classes were listed simply as 8^{th} grade math courses. The 12^{th} grade courses consisted of one algebra III course, 2 advanced topics in mathematics courses and 3 pre-calculus classes. One of the 12^{th} grade mathematics pre-calculus classes had eight 11^{th} graders and three 10^{th} graders within the senior pre-calculus math course. In response to question 27, all of the students were in the same local school district within the same state.

In addition to these 28 questions, there were also 6 questions for students pertaining to their perceptions on calculator usage and access to calculators in the classroom, which are numbered 29 to 34. Question 29, 30, and 33 asked students' usage in their classrooms. Question 31 and 32 asked their confidence level in understanding of mathematics coursework, as well as in asking questions in their mathematics class. Question 34 asked students to write about their views on calculator usages in their mathematics class, focusing particularly on their reasoning. Questions 28 to 33 included statement questions in the form of a 4 level Likert scale to determine the level of agreement, or disagreement, with the prompts. The last question asked students to specifically share if they believed they needed a calculator in class. If they answered negatively or affirmatively, they were included. If they were unable to choose, they were not included in this second sample. Similarly, with the other Likert scale statement questions, gender prompts and ethnicity responses, only students who answered these statements were in this phase of analysis. As a result, 231 students were included in the subsequent student quantitative analysis.

Gender difference.

Question 25 specifically asks the gender of the student. Based on gender, there were similar average scores for the assessment. There was no statistically significant difference between the males and the females. The analysis of variance produced a level of significance of 0.658 which is above the value of 0.05. See Tables 7 to 9.

Table 7

Gender and FMSA Scores

Total Scores								
Gender (Male:1, Female: 2)	Mean	N	Std. Deviation	% of Total Sum	Variance	Sum	Minimum	Maximum
1	12.90	109	3.911	47.6%	15.295	1406	5	21
2	12.66	122	4.135	52.4%	17.101	1545	3	21
Total	12.77	231	4.024	100.0%	16.193	2951	3	21

Table 8

ANOVA Table of Gender and FMSA Scores

			Sum of Squares	df	Mean Square	F	Sig.
Total Scores * Gender (Male:1, Female: 2)	Between Groups	(Combined)	3.183	1	3.183	.196	.658
	Within Groups		3721.111	229	16.249		
	Total		3724.294	230			

Table 9

Measures of Association

	Eta	Eta Squared
Total Scores * Gender (Male:1, Female: 2)	.029	.001

Ethnicity difference.

Question 26 asks students to label their ethnicity. The highest mean discovered was for the smallest sample, Native American students. This small group also represented the largest standard deviation of 4.827. The lowest standard deviation was from students who classified their ethnicity as Other. The lowest mean was from students who recognized their ethnicity as Hispanic. The largest ethnic groups represented were students who distinguished themselves as black students.

Table 10

Ethnicity and FMSA Scores

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
1	63	12.95	4.058	.511	11.93	13.97	3	21
3	14	12.00	4.261	1.139	9.54	14.46	6	18
4	12	12.50	4.359	1.258	9.73	15.27	7	20
5	5	14.60	4.827	2.159	8.61	20.59	9	19
6	92	12.91	4.097	.427	12.06	13.76	4	21
7	45	12.36	3.694	.551	11.25	13.47	6	20
Total	231	12.77	4.024	.265	12.25	13.30	3	21

Legend: 1 (white), 2 (Pacific Islander), 3 (Hispanic), 4 (Asian), 5 (Native American), 6 (black), 7 (Other)

The two largest ethnic groups represented included black and white students, respectively, see Table 10. The next largest group classified themselves as Other. This group includes student from biracial and other blended ethnicities. Each of these three groups individually far exceed the number of the other ethnicities, combined. In order to compare ethnic groups' fundamental mathematics skills the three groups were consider since the had a significant number in each of the three samples. However, since the group classified as other includes many different groups, the two groups with the highest number of students, black and white, were selected to compare.

Table 11

Group Statistics for Black and White Students

	Ethnicity (White:1 Pacific Islander: 2, Hispanic: 3, Asian: 4, Native American: 5, Black: 6, Other 7)	N	Mean	Std. Deviation	Std. Error Mean
Total Scores	White: 1	63	12.95	4.058	.511
	Black: 6	92	12.91	4.097	.427

The means for both the black students and the white students were closely aligned. The means differed by four hundredths of a point. The standard deviations were also similar between the two groups. A comparison was also conducted in the form of a t-Test to see if a statistically significant difference existed between the two ethnic groups in terms of the mean scores. See Tables 11 and 12.

Table 12

Independent Samples Test for Black and White Students

	Levene's Test for Equality of Variances	t-test for Equality of Means

		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Total Scores	Equal variances assumed	.009	.93	.059	153	.953	.039	0.67	-1.279	1.358
	Equal variances not assumed			.059	134.210	.953	.039	0.67	-1.278	1.357

The level of significance between the white students and the black students' mean score is 0.953 which is not statistically significant. Therefore we do not reject the null hypothesis in this case.

Qualitative Results: Student Survey

Student perception on calculator usage in learning of mathematics.

Students feel that they need a calculator in their mathematics course. They believe that one will be provided if they do not have one. Furthermore, students believe that the calculator access and usage includes classwork and instruction time. Even though many students Strongly Agree in calculator access and usage, less Strongly Agree in their confidence in their understanding of their mathematics coursework. The students, overall, feel comfortable asking questions in their mathematics class. Students do not all agree that they can use the calculator on exams. Although most students believe they can Always or Sometimes use a calculator for exams, there is a group who believe that they can Never or Hardly Ever use the calculator for exams.

Questions 29 and 30 have similar pie chart responses from students. Students Strongly Agree or Agree that they can use calculators in class and that if they do not have a calculator, one will be provided for them. For questions 31 fewer students Strongly Agree in their confidence level in understanding of their mathematics coursework. Students Agree or Strongly Agree that the atmosphere in their classroom is conducive to asking questions. However, question 33 has a relative spike in responses to Never and Hardly Ever when asked if students can use calculators on mathematics exams.

Table 13

Q29 I Can Use a Calculator in my Mathematics Class During Classwork and Instruction

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	98	42.4	42.4	42.4
	2	106	45.9	45.9	88.3
	3	21	9.1	9.1	97.4
	4	6	2.6	2.6	100.0
	Total	231	100.0	100.0	

Note: Strongly Agree: 1, Agree: 2, Disagree: 3, Strongly Disagree: 4

Most of the students Strongly Agree or Agree that the calculator is permissible during instruction and during classwork for their mathematics class. Some of the students were observed with their own graphing calculator in class. Most students were not seen bringing a graphing calculator to class.

Table 14

Q30 If I Do Not Have a Calculator, One is Provided for me in my Mathematics Class

		Frequency	Percent	Valid Percent	Cumulative Percent

Valid	1	109	47.2	47.2	47.2
	2	87	37.7	37.7	84.8
	3	26	11.3	11.3	96.1
	4	9	3.9	3.9	100.0
	Total	231	100.0	100.0	

Note: Strongly Agree: 1, Agree: 2, Disagree: 3, Strongly Disagree: 4

Most students Strongly Agree or Agree that a calculator is provided for them in class, if they do not have their own calculator as seen in Table 14. Few students Disagree or Strongly Disagree with that claim. During the study, calculator classroom sets were observed in the mathematics classrooms. The calculator classroom sets were comprised of dozens of graphing calculators and clearly displayed and accessible for student use.

Table 15

Q31 I am Confident in my Understanding of my Mathematics

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	45	19.5	19.5	19.5
	2	143	61.9	61.9	81.4
	3	34	14.7	14.7	96.1
	4	9	3.9	3.9	100.0
	Total	231	100.0	100.0	

Note: Strongly Agree: 1, Agree: 2, Disagree: 3, Strongly Disagree: 4

Students both Strongly Agree and Disagree with their confidence level in mathematics. Although most students Agree that they have confidence in their understanding of mathematics course work, students both Strongly Agree and Disagree with their confidence level in mathematics, in Table 15. In other prompts, more students Strongly Agree in terms of calculator access and calculator use in practice for classwork and instruction than they do for confidence level in understanding mathematics coursework.

Table 16

Q32 I Feel Comfortable Asking Questions In My Mathematics Class

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	79	34.2	34.2	34.2
	2	111	48.1	48.1	82.3
	3	31	13.4	13.4	95.7
	4	10	4.3	4.3	100.0
	Total	231	100.0	100.0	

Note: Strongly Agree: 1, Agree: 2, Disagree: 3, Strongly Disagree: 4

As seen in Table 16, the comfort level is high in the classroom for students as it relates to asking questions. The atmosphere is conducive for both 8th and 12th grade students to ask questions if they have a concern or want clarification on topics. Few students Disagree or Strongly Disagree with the high comfort level for asking questions in the classroom.

Table 17

Q33 I Can Use a Calculator For My Mathematics Exams

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	43	18.6	18.6	18.6
	2	104	45.0	45.0	63.6
	3	44	19.0	19.0	82.7
	4	40	17.3	17.3	100.0
	Total	231	100.0	100.0	

Note: Strongly Agree: 1, Agree: 2, Disagree: 3, Strongly Disagree: 4

Table 17 reveals that question 33 resulted in more Hardly Ever responses than the previous questions. There was a larger group of students who answered Hardly Ever, when prompted about the permission to use calculators during testing in their mathematics classes, than for the other questions regarding access and use of calculators during instruction and for classwork. Although the most popular response was Sometimes, there was a split between Always, Sometimes and Hardly Ever between both the 8th and 12th graders for calculator permission during exams.

Student reasoning for calculator usage in mathematics classes.

Question 34 has the following prompt: "I believe that I need to use a calculator in my mathematics class. Please explain why or why not below." There were blank lines immediately after the prompt for students to elaborate on their reasoning. A 62% majority of students believe that, yes, they do need to use a calculator in their mathematics class.

Table 18

Q33 I Can Use a Calculator For My Mathematics Exams

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	143	61.9	61.9	61.9
	No	88	38.1	38.1	100.0
	Total	231	100.0	100.0	

The students who believe that they do need a calculator have a slightly higher mean score than those who do not believe that they need a calculator, as seen in Table 18. The initial statistics were incorporated in question 34 to see if there were marked differences between students who have confidence in their mathematics skills without a calculator based on those who do not. There were no pronounced differences between these two groups. This reveals that although students have a belief in their need for calculator usage, they have virtually no difference in scoring than students who believe they do not need a calculator. The calculator, on its own, does not produce higher scores on the FMSA.

Table 19

Q34 I Believe I Need to Use a Calculator Descriptive Statistics

Total Scores * Q34 (Yes:1, No:2)

Total Scores

Q34 (Yes:1, No:2)	Mean	N	Std. Deviation
Yes	12.90	143	4.281
No	12.68	88	3.958
Total	12.82	231	4.154

Table 19 exhibits the mean score of students who responded affirmatively or negatively to Question 34. This question was also a unique one because it provided students with the opportunity to share their explanations on why they believe they need a calculator in class or why they do not feel that it is necessary in their mathematics class. Table 20 below shows that some responses were made more frequently than others. The more popular responses are grouped and a sample from the student responses for and against the need for calculators accompanies each of these responses, if both options exist. A detailed summary of the group responses is included along with the percentage of students who responded out of the total.

Table 20

Q34 Detailed Summary

Q34	Category Responses	N	%
YES	I find the calculator helpful in my math class	26	11.3
NO	I do not find the calculator helpful in my math class	9	3.9
YES	I need a calculator to perform mental math	11	4.8
NO	I do not need a calculator to perform mental math	17	7.4
YES	I need a calculator check my work	20	8.7
NO	I do not need a calculator to check my work	4	1.7
YES	I need a calculator to save time	23	10.0
NO	I do not need a calculator to save time	0	0

The most popular response for why students agreed and answered yes, to their need for a calculator, was that it was helpful. 26 students specifically shared the calculator was important in assisting when they needed help.

- Yes; a calculator is helpful when the question is hard to solve it without a calculator.

Conversely, 9 students responded that the calculator was not ultimately a help to them.

- No; I do not believe this because I have never used one this year and I have a good grade plus it doesn't help me.

One of the most common responses was in reference to the use of mental math skills. There were 11 students who responded with yes and 17 students who responded with a no.

- Yes; I can't do complicated problems all in my head.

- No; I believe we shouldn't use a calculator in my math class because during testing time, if a calculator is not provided, we should know how to solve problems on our own.

Another popular response was checking work. 20 students responded with a yes to their need for a calculator to check work and 4 responded with a no to requiring a calculator, but enjoying the option to check work.

- Yes; because I like to justify my answer or check my work.
- No; don't need a calculator, but nice to have, to check my work.

The issue of saving time as a reason why students need to use a calculator came up 23 times affirmatively and not at all negatively.

- Yes; sometimes using a calculator helps me save time instead of having to write out all the steps.

Qualitative Findings: Teacher Interviews

The essential question posed for the qualitative strand was "how do 12th grade math teachers and 8th grade math teachers perceive calculator usage in their mathematics teaching, and how do they describe their experiences in teaching and learning of mathematics in terms of necessary repeated practices for fundamental mathematical skills?" The qualitative semi-structured interview was conducted to collect qualitative data. A total six of teachers were participated in the interview.

I met with and spoke with each of the six teachers on several occasions. There were four phases to the interactions with the teachers for both the 8th grade and the 12th grade students. Three phases encompassed the following interactions with only the teachers: introductions, semi-structured interviews questions and responses, and finally, the perceptions from teachers based on the initial descriptive statistics. Each of these phases lasted for less than 10 minutes each. The fourth phase focused on data collection from students while in the teachers' classroom. This phase was initially thought to take about 20 minutes, based on a pilot. However, it was approximately close to 35 minutes in a classroom setting for each class. Three of the four phases occurred before the quantitative data were compiled and analyzed: the introduction, the semi-structured interviews and responses, and the data collection from the students. After the initial descriptive statistics were tabulated, the final phase occurred: gathering of the perceptions from teachers based on the initial descriptive statistics.

The set of teachers who taught middle school each had several classes with only 8^{th} graders. The first teacher in the eighth grade will be referred to as Teacher Eighth 1 (TE1) and the latter as Teacher Eighth 2 (TE2). The next group of teachers taught twelfth graders. The first set taught at the same school and each of the teachers taught 12^{th} graders mathematics, but the first one of them had a class with different grade levels in one 12^{th} grade mathematics course and the second teacher had fewer 12^{th} grade students. The first teacher in this group will be referred to as Teacher Twelfth 1 (TT1) and the second as Teacher Twelfth 2 (TT2). Finally, the last couple of teachers taught solely12^{th} graders for several different classes at the same high school. They are referred to as Teacher Twelfth 3 (TT3) and Teacher Twelfth 4 (TT4).

The first two interviews were conducted after email correspondence in a face-to-face format in a classroom with each of the high school teachers. Each participating teacher was asked the same series of five questions during the interviews. The teachers were given the option of elaborating as much or as little as they felt comfortable sharing. The first two questions summarized the ability of the students to perform fundamental mathematical skills and how the students acquired their skill level before entering into the individual teacher's classroom. The next two questions specifically asked if there were review strategies during instruction time on the fundamental mathematical skills or if there techniques to assist in these fundamental skills. Finally, the journey to teaching mathematics was asked of each teacher at the conclusion of the semi-structured interviews. This enabled the teachers to share their process to teacher status and it confirmed that the background of the teachers included both highly skilled and highly qualified teachers.

Teacher Perception on Student Calculator Usage

Student ability to perform FMS without calculator usage.

The first question asked participating teachers to describe the ability of your students to perform fundamental mathematical skills, without calculator usage. All of the school teachers shared that the abilities of their students varied across a wide spectrum of skill levels. They viewed that some students had stronger skills and other could perform fundamental mathematics if they participated in supplemental instructional review first, and other students simply did not have those skills at their current grade level, whether 8^{th} or 12^{th} grade.

Specifically, TT1 stated that some students are excellent and some are getting better. The teacher also shared that in their classroom the students are “accustomed to using the calculator for everything.” TT2 shared the students are “dependent on the calculator for basic math skills.” TT3 noted that it “depends on the level of the student. Honors handle decimals easier and may rely on calculator for dividing. Students would need a refresher on long division.” TT4 asserted that there is a “mix because some students are pretty good and others lack skills.” Furthermore, TT4 shared that the students “might be able and don’t have the desire, then they may use the calculator as a crutch. Students have a fear of fractions and may not try.”

TE1 believes that the “ability is there but students use the calculator as a crutch.” TE2 noted that they “have a range of kids and a range of skills” in the classroom.

Teacher perceptions on how students acquire FMS

Fundamental mathematics skills are defined as skills required for students from K-7 grade, according to the Common Core State Standards (CCSS) for mathematics. All of the teachers believe that students should have these skills before entering their classroom, however, the teachers also acknowledge that they have students that demonstrate their knowledge of these skills is lacking.

TE1 believes that if you “don’t give them a calculator it forces them to use skills.” TE2 believes that students should have “already figured basic math skills” before the 8^{th} grade. TT4 states that “repetition at the elementary and middle school” levels are where students develop fundamental mathematics skills. TT3 states that the basic skills are acquired in “earlier grades in elementary school when they cannot use a calculator.” TT3 further iterates, “Not sure when it gets lost. Students respond like they have never done this before when a calculator becomes a tool to replace brains.” TT2 stated that “we had to memorize the multiplication facts for integers up to 12 and I think that is not happening now.” TT1 agreed that “before my class” students should already have basic skills before high school.

Strategies or techniques, if any, for students to ultimately improve fundamental mathematical skills

If they observe, or perceive during instruction, that students do not have fundamental mathematics skills, participating teachers indicated that they might consider making adjustments in instruction. The school teachers were a bit divided on whether or not to take on the role of reviewing material that is really years prior to their students' current curricula.

TE1 promotes fundamental mathematics skills improvement by having students "show your work" and exhibit the computation. TE2 incorporates "using different wording, especially for subtracting a negative." In addition, a common technique from TE2 is to use comparisons of money to assist students with the concept of subtracting a negative signed numbers.

TT1 "teaches using different techniques" in order to improve fundamental mathematical skills for students. TT2 does provide a "memorization table for students who choose to practice it." For other classes this teacher also incorporates ½ lessons with a calculator and ½ without it to build up skills for students who still have problems with integers and signed numbers.TT3 encourages students to "practice and try" while providing a little refresher and encouraging students to "take your time." TT4 "tries to show without a calculator" steps in mathematics to the class as an option.

Parameters or limits for calculator usage in your classroom: calculators permitted on exams or not permitted during in class coursework instruction.

All participants permit calculator at some point in instruction, classwork or on assessments. There are differing levels of calculator usage and access, depending on the teacher. One teacher may wait until after order of operations lessons are complete or signed numbers are taught, but in each case, the calculator becomes part of the option for student learning.

TE2 has no limit on calculator usage in their 8th grade classroom. "I believe calculators can speed up things." TE2 will actively "teach different ways to use the calculator and how to use them in preparing for the SAT." TE1 will not allow calculators in the beginning of the year or during the review of integers. After that, TE1 will "teach how to use calculators.

TT2 state there is "no limit" for calculator usage in their mathematics classes. TT4 states there is "no limit" for calculator usage in pre-calculus classes. TT1 shows students show to graph without a calculator in pre-calculus, however there is "no limit" for calculator usage in the classroom. TT3 teaches a portion of algebra 1 without a calculator. This section introduces signed numbers and order of operations. After that and for all other courses there is no limit and students are then "welcome to use calculators are much as they like."

The journey to becoming a mathematics teacher

The participating teachers are all committed to mathematics instruction. They all have certification in their fields and the credentials and education to sustain their status as mathematics teachers. Two participants are mathematics chairs at their respective schools. One at the middle school level and one at the high school level. The experience ranges of the six teachers ranges from the newest at 2 years to over 20 years of experience in teaching mathematics.

TE1 had 7 years of teaching experience and was always strong in mathematics. After changing careers, TE1 pursued and completed the certification for mathematics instruction. TE2 changed majors before completing the degree to teach mathematics. TE2 has over 5 years of teaching experience.

After completing college, TT4 always planned on being a mathematics teacher. TT4 has over 8 years of teaching experience. TT3 has over 20 years of experience and is a mathematics chair. TT3 was always skilled in mathematics and after a change of major in the first year of college, never looked back from a mathematics career. TT1 graduated with honors and knew in high school that a mathematics-teaching career was in the future. TT1 has over 10 years of teaching experience. TT2 recently graduated with a master's degree in mathematics education and has 2 years of teaching experience.

Teacher Responses to Initial Descriptive Statistical Findings

For the second part of the Qualitative Data Analysis, each participant was provided with the descriptive statistics included again in Table 2, below.

Table 2

8th and 12th Grade Descriptive Statistics

	8th and 12th	N	Mean	Std. Deviation	Std. Error Mean
Sum Correct	8th Grade	194	13.08	4.193	.302
	12th Grade	109	11.83	3.993	.382

TE2 expressed "shock" at the results, initially. Follow-up questions asked about the questions themselves and the style of the solutions sets. Plausible conclusions from TE2 were that at some point there was a change in the curriculum which afforded the 8th grade student an opportunity to practice mental math in a way that 12th graders were not. Perhaps the cell phone did "fry the brain completely" of the 12th graders. Finally, perhaps the 8th grade student have developed test taking strategies that are different than those of the 12th grade students.

TE1 paused initially at the results. After a short consideration TE1 stated that the caliber may be higher in "high school vs. the mental math expectation in middle school." Furthermore perhaps, "computation may be less important as long as the student knows higher level concepts.” However, TE1 pointed out that “in some college classes they don’t use the calculator in college.”

Responses to Table 2 were varied overall between the schoolteachers. One expressed genuine surprise with the 8th graders having a higher average than the 12th graders. Others expressed surprise that the 8th graders did not score even higher considering that they are closer to doing the basic fundamental mathematics topics in more recent years than the high school seniors.

TT3 shared that the results were “surprising, yet not surprising.” TT3 noted that students at the high school level have not been involved with the basic concepts as recently as the middle schoolers. In fact, there was “surprise that the 8th graders did not score higher.”

TT2 responded, “I can see that,” when initially presented with the data. “They don’t have it, the basic math skills,” responded TT2. For a plausible reason for the results, TT2 shared that the material may be “more fresh” to the 8th grade students and the 12th grade students may not have been exposed because “it has been a while” for them since they last did this type of mathematics.

Bridging Quantitative Results and Qualitative Findings

This mixed methods study aimed to answer the question of how educational leaders can address the long term impact of the incorporation of calculator usage in U.S. secondary mathematics. Data analysis indicates that participating teachers and students consistently have the same consensus. Calculators are needed in the classroom for computation, exams and instruction. Teachers express that students lack fundamental mathematics skills and they believe that students should already know basic facts before entering 8th grade and certainly by 12th grade.

Based on the quantitative result of this study, fundamental mathematics skills are eroded, particularly at the high school level. According to qualitative data including students' responses to the survey and teachers' interviews, the current teaching and learning of mathematics is leaning toward introducing calculator usage, with no limits, earlier rather than later, based on this study. That, given the quantitative data in this study, appears to be problematic. The more students are provided with all access to calculator usage for topics that require fundamental mathematics skills, the more likely these skills may be worn away, over time. If the student lacks these skills to begin with, there becomes a diminishing opportunity for these skills to be developed, as the student matriculates to the end of middle school and particularly once the student begins high school.

According to participating teachers, in order to address these concerns, the teachers have employed several creative strategies of improving skills. These included presenting material in different formats, comparing ideas to real world situations and providing extra help in the form of practice worksheets. However, even with these strategies, the majority of students express a need for a calculator in their coursework.

According to Cognitive Load Theory, Sweller asserts that the cognitive process is twofold, requiring the acquisition of knowledge and the transfer of learned procedures to automatic (1994). Students need to practice skills in order to retain them, according to the responses from the teachers in this study. A common theme was that with a refresher, students would be more likely to improve their skill level. This type of review would take up valuable instruction time, therefore parameters would have to be set on what counts as review and when it is to be introduced and on what topics. All of these concerns would need to be incorporated in a curriculum plan agreed on by the districts. This type of intervention in terms of limiting calculator usage and increasing practice and review of fundamental mathematics skills are ways that higher education leaders can address the long term impact of the incorporation of calculator usage in U.S. secondary mathematics.

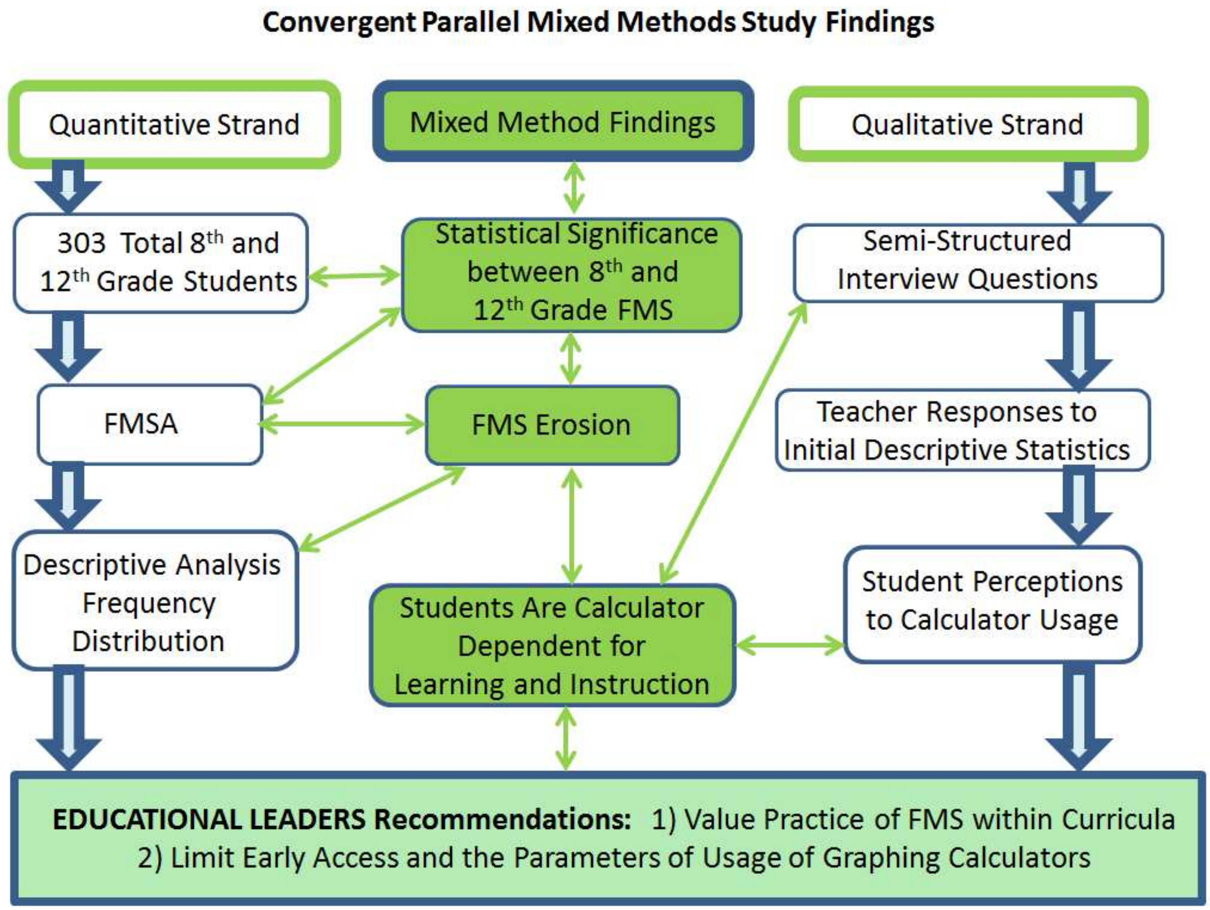

Figure 7. Findings of the Convergent Mixed Methods Study.

CHAPTER 5: DISCUSSIONS

There is a consistent use of calculators in secondary schools in the United States. As an instructor, my experience with students exposed their lack of fundamental mathematics skills at the high school and college level. I wondered how a student could enter high school without the ability to perform rudimentary mathematics. Then I noted the graphing calculator sets provided to me and the class. A student can move through math courses without some very basic abilities if they are permitted to use a calculator, without limitations. The purpose of this mixed method study was to quantitatively examine calculator usage effects in secondary education by comparing the fundamental math skills of 8^{th} and 12^{th} grade students and to qualitatively explore secondary school math teachers' perceptions on calculator usage in the classroom.

The argument is not against the use of technology in mathematics classrooms. The concern is the early introduction of calculator usage and the limited demonstration of fundamental mathematics skills, as evidenced in the FMSA administered without a calculator for both 8^{th} and 12^{th} grade mathematics courses. Although there may be a myriad number of reasons for U.S. students' mathematics proficiency declining, this study was restricted in focus to one main focal point: calculator usage as a potential factor in FMS. This laser focused look at calculator usage did not look at other factors including: socioeconomic status, family structure, numerous locations and countries, or other various potential influences. For this mixed method study, the math assessment was employed to specifically examine participating students' fundamental math skills, and the semi-structured interview was concurrently conducted to explore teachers' perceptions on calculator usage.

The quantitative strand for this study began with a hypothesis that there would be no statistically significant differences between 8th and 12th grade students in terms of their fundamental mathematical skills. Quantitative data analysis, however, indicated that 12th grade students did not have a statistically significant improvement over the 8th grade students in fundamental mathematical skills. The 8th graders outperformed the 12th graders, to my surprise. The 8th grade students outperformed the 12th grade students in over 80% of the questions. I did not expect that. I thought the scores would be virtually the same, based on my experience. However, over time, the potential erosion of fundamental math skills may place students farther back mathematically than initially anticipated. My initial thought was that the 12th grade students would perform marginally higher than the 8th grade students, but not statistically significantly better. The findings in this case were a bit surprising. As a result, the hypothesis was rejected because there *was* a statistically significant difference between the 8th and 12th graders' fundamental mathematical skills. The difference was in favor of the 8th graders. It is concerning because the 12th graders have 4 more years of mathematics than 8th grade students. However, when it comes to the basic fundamental mathematics skills as assessed without a calculator, in practice they may actually have less recent practice time because of the prolific access and use of calculators.

The reason for this overall improved average by the 8th grade students may likely be, in part, because the 8th graders presumably have not had the use of calculators for the last four years. Qualitative data analysis indicated that all of secondary mathematics classes assessed employ rigorous use of calculators at some point in the semester, even if it is after specific topics in mathematics sections are completed. Three of the six teachers have no limit to calculator usage in their classes. The teachers agreed that although students may lack basic skills, practice is important and beneficial. This study also revealed that the review of fundamental mathematics skills is not the top priority in their class, especially at the 12^{th} grade mathematics level. All of the teachers believe that students should already know the basic facts before their course begins. The teachers conceded with practice worksheets and other strategies to improve fundamental mathematics skills.

The 12^{th} grade students have been reaching for the calculator and are "accustomed to using the calculator for everything" according to TT1. TT4 responds to the lack of fundamental skills with, "not sure when it gets lost." The fundamental mathematics skills of 12^{th} grade students are seemingly eroded by the time senior year begins for many students. There may be many factors, in this study we look closely at calculator using because of the virtually unlimited practice of calculator usage. There are also limits on review and practice of fundamental mathematics skills, once high school begins. There is limited opportunity, in practical classwork and instruction, for review of fundamental skills if calculators are provided in class, permitted during quizzes and allowed for exams. This custom of increased calculator usage is not only relegated to 12^{th} grade students. This routine of teaching students how to use a calculator is prevalent for 8^{th} grade students as well. TE1 and TE2 teach students how to use graphing calculators. TE2 argues that "calculators can speed up things." Students need practice in mathematics. The practice reinforces concepts and makes them ingrained and automatic. That is true of calculator usage, as well. The repetition of reaching for a calculator can also become habitual.

However, in order for students to have mastery of a skill, they need to demonstrate that they have proficiency. If a student masters one concept, mathematically, they have then met the guidelines to move on to the next skill level (Maxwell, 2016). According to Cognitive Load theory, the precursor to grasping advanced levels in mathematics is the demonstration of basic fundamental mathematics skills. If a student does not have a firm grasp of fundamental mathematics skills, the subsequent mathematics courses become more and more challenging. Additional advanced math courses will only expose the gaps and weakness in skill levels. Mathematics is a discipline that builds on the fundamentals. The whole language of mathematics requires a set of rules to be understood and applied before you go to the next level, and so on. It is difficult to skips steps in mathematics if you don't know the foundational cornerstones.

Students responded affirmatively to the survey for Q29: I can use a calculator during classwork and instruction and for Q30: If I do not have a calculator one will be provided for me. The teachers responded that the student abilities in performing fundamental mathematics skills was varied across a wide spectrum. The teachers instruct students on how to use the graphing calculators. The current curricula are essentially designed for calculator usage across both 8th and 12th grade. Class calculator sets are provided so that students will be skilled in using the calculator. This will definitely speed things up during instruction. However, the procedural use of calculators allows for a lack of mathematics skills to be overlooked. The systemic use of calculators can rob student of being afforded the opportunity to practice their fundamental mathematics skills. Furthermore without the opportunity to practice and look at answers and see if those answers are reasonable results in shortchanging the mathematical reasoning process. More confidence may be placed on the calculator than on the credibility of results on the screen. A healthy math skill set will prompt a student to check and see if a calculation is correct or entered correctly. Without that skill, there is virtually no way of telling if a solution is plausible.

Q34 prompted students on the belief that they need a calculator in their mathematics class. The majority of students in both 8th and 12th grade agreed and believe that they need a calculator for their math class. The teachers respond that student should have the basic fundamental mathematics skills before the 8^{th} and certainly before the 12^{th} grade. Teachers also responded that practice and repetition of skills can improve math skills. The students who responded that they need a calculator had no statistically significant different score than those who feel that they do not need a calculator. Therefore, the students may lack confidence in their mathematics skills and believe that without a calculator they are lost. Future research needs to review current standards, curricula and instructions on calculator usage to assist students to develop fundamental mathematics skills, because the habit of reaching for a calculator may not be limited to student practice alone. It is also part of the way the students have been taught to learn mathematics, in many ways. The current routine provides students access to use a calculator and teaches them to use one on a consistent and repetitive basis. Perhaps there is a better way.

Recommendations to Educational Leadership

Educational leaders have an opportunity to address the potential erosion of the fundamental mathematics skills of students. Fundamental math skills are critical for students to succeed mathematically as they progress toward higher education. Without the basic foundation in math skills, higher level topics are hindered. Without these early math skills, some career paths may be limited. Instructional leadership theory focuses on the leader of an institution driving the learning climate. These fundamental math skills require practice in order for students to keep them and not erode backwards, as was the case with the 12^{th} graders in the FMSA. Math courses need a component in which basic skills are required to be demonstrated without a calculator. This component should be in the curriculum so that students know what is expected of them at the beginning of the course.

Calculator over usage as a practice exists in middle school and in high school, as evidenced by this study. Currently the mathematics teaching and learning environment has calculator skills as a large part of instruction and focus. The calculator is only a tool. This tool spends a lot of practice time in math courses, even at the lower 8^{th} grade level. The time spent on calculator skills can be shared with practicing fundamental mathematics skills, math computation skills and math reasoning skills. These skills will require students to think about solutions and strategies for problem solving. More importantly, these types of skills can be practiced in context and have a long lasting reach in terms of higher level mathematics and additional math skills. Because instructional leadership encompasses clearly articulating a school's mission, a more mathematics focused vision and mission in a school district could greatly impact the way students, and teachers, spend their instruction time. The time spent on instructing students on graphing calculator competencies can be utilized by practicing using other strategies for solving math problems and other strategies for graphing and other techniques for solving equations. Calculator time is important and is probably here to stay, however it has usurped its place as a supplement to instruction to becoming the provision for student instruction.

Finally, students believe that they need a calculator in their mathematics class, even as early as the 8^{th} grade. This is of significant concern at the 8^{th} grade level. If students feel already that they need a calculator, when did this start? How early are students actually being introduced to the calculator? The indoctrination of the calculator as necessary, or required, for 8^{th} grade math is problematic. Students' belief in their dependence on a resource at this young stage in math development is of more concern than the 12^{th} graders belief in their dependence. What topics are 8^{th} graders covering that they already believe that they are in need of this support? Why would it ever be a good idea to feel that you need this device if you are at a level of algebra

I or even at a math level preceding algebra I? Several 8th graders, who were assessed, were at pre-algebra I level. Instructional leadership gives the authority to the leader to institute and make change. If the changes are reflected upon and agreed by teachers and district leadership, perhaps the changes can "support students to engage in cognitively demanding tasks and construct solutions to tasks that require students to make sense of the mathematical relationships at hand," (Rigby, Larbi-Cherif, Rosenquist, Sharpe, Cobb, & Smith, 2017, p 638).

In terms of educational leadership addressing the long-term impact of the incorporation of calculator usage in U.S. secondary mathematics, the recommendation is two-fold. Review, as a valuable priority, is part one. Review is valuable in learning and in building mathematical skills. Review of skills and reinforcement of skills as a requirement of skill improvement was a consistent response amongst the teachers. The idea that review is valuable is an important one in math education. As much as review of old material should not take up entire class times, it is still a valuable concept that should not be ignored.

The second part of the recommendation supports the first: limit the early introduction of calculator usage and have parameters of use. If students expect that they are required to know basic fundamental mathematical skills, without a calculator, they will be more inclined to practice those skills. If teachers have a place in their curricula for limited calculator usage, they can create assessments that support demonstrating those skills.

Students are provided with graphing calculators at the middle and high school level if they do not have their own. That is one of the unique observations in U.S. mathematics instruction: how early and how often the calculator is used. This has become a trend in the negative direction. Most educators and students would agree that calculator usage and access is important in education. Basic fundamental mathematical skills are important, too. These skills still need practice by students.

Students require practice in order to retain information so that it becomes ingrained or automatic. Mathematics skills are typically layered in terms of requiring a firm foundation in order to move ahead. Students shared their need for calculators in the FMSA. Most students believe that they need a calculator. That is consistent with 8^{th} grade students and with 12^{th} grade students. Without these basic skills it becomes increasingly difficult to move forward and excel mathematically. For that reason, the lack of skills that may be hidden with a calculator in hand may be exposed in other courses that rely on the foundational concepts of mathematical understanding.

Future Research

The next phase of this investigation would be to look at elementary schools and determine if there is indeed a trend of calculator introduction as early as the 4^{th} grade. This research would include elementary and early middle school students as participants as well as parent perspectives. The perception of parents could be conducted in a face to face format in the same type of style as the teacher interviews. The middle school students and elementary students would participate in the mathematics skills assessment that would also be implemented. My goal would be to compare two grade levels: one in elementary and one at the middle school level between 5^{th} and 7^{th} grade, inclusive. Although this FMSA assessment was conducted during the beginning of the school year, in future assessments, I think it would be beneficial to conduct skills based assessments when students are closer to the half way completion mark of a term, or at least nearer to the end of the term. The typical class practices would be further solidified and perhaps students may have more concrete responses. Also, students may have covered more material in their classes and the scores may be higher across the board. Also, in future assessments, I will plan to have more questions for quantitative analysis which would give an opportunity for a greater variety of incremental scoring. In addition, if questions have different weights, the same result can be achieved. Furthermore, several students asked about the ethnicity question. I would plan to have the option of allowing students to describe their ethnicity in their own way in future assessments containing an ethnicity prompt. Some students shared that their ethnicity was not accurately labeled in the survey.

I did not see much literature on the use of calculators in the classroom when I began my research. This study should add to the body of literature on the investigation of the impact of calculator usage on fundamental mathematics skills. This study is unique in that it looks at calculator usage in the classroom and its potential impact on fundamental mathematics skills from two different points of view. The quantitative look coupled with the qualitative strand involves a deeper level of research, but it was worth it for this study. The calculator and its increased use in secondary education are important from the standpoint of the teacher as well as the student. Each group shared important perspectives and as an investigator I had the opportunity to compare and contrast those findings and hopefully make recommendations that will improve student fundamental mathematics skills.

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Appendix A

Fundamental Mathematical Skills Assessment (Quantitative)

Directions: Answer all questions by circling the correct response. Calculators are not permitted.

1. Add 0.9755 + 1.22 +3.005 + 0.0012

   A. 5.2017
   B. 5.1972
   C. 5.2080
   D. 531967
   E. 5.1772

2. 3 x 4 x 2 equals

   A. 24
   B. 9
   C. 14
   D. 18
   E. 16

3. 84% equals

   A. 0.084
   B. 8.4
   C. 0.0084
   D. 0.84
   E. 8.04

4. $-23 + 11 + -16$ equals

   A. -28
   B. 28
   C. 4
   D. 18
   E. -18

5. $8.46 \div 1.5$ equals

   A. 5.6
   B. 5.46
   C. 5.44
   D. 6.54
   E. 5.64

6. $(6 \div 2) - (3 \times 0)$ equals

   A. 1
   B. 0
   C. 3
   D. 4
   E. 9

7. $1.52 \div 0.1$ equals

   A. 1.52
   B. 15.2
   C. 0.152
   D. 152
   E. 1.522

8. $(4 \times 1) + (2 \times 3)$ equals

A. 9

B. 11

C. 10

D. 12

E. 24

9. $7 \div (2 + 5)$

A. 0

B. $\frac{1}{2}$

C. 3

D. -1

E. 1

10. Add $3.1289 + 0.004 - 83.4 + 901.16$

A. 987.6929

B. 920.1189

C. 920.0829

D. 919.9893

E. 920.8929

11. $\frac{4b}{2} + 3 = 11 + b$

A. 4

B. 8

C. 6

D. 11

E. 1

12. Frank paid 5% sales tax on his television, which cost $769 before taxes. What did the television cost in total?

A. $730.55

B. $38.45

C. $807.45

D. $738.45

E. $769.50

13. $4 > z < 3$

A. $z = 2$

B. $z = 7.1$

C. $z = 3.5$

D. $z = 5$

E. none of the above

14. $-3(5 - 2y) =$

A. $30y$

B. $-15 - 6y$

C. $-15 + 6y$

D. $9y$

E. $15 - 6y$

15. A movie theater sold 422 tickets on Friday. On Saturday, they sold 518 tickets. What was the approximate percentage that ticket sales increased on Saturday?

A. 23%

B. 122%

C. 123%

D. 42%

E. 96%

16. 0.45 + 0.35 equals

A. 8.0

B. 0.1

C. $\frac{8}{10}$

D. $\frac{5}{10}$

E. $\frac{7}{10}$

17. Which of the following is not equal to the others?

A. 0.50

B. $\frac{1}{2}$

C. 50%

D. $\frac{2}{1}$

E. $\frac{2}{4}$

18. If 8 is 40% of a number, what is 15% of the same number?

A. 20

B. 1.2

C. 3

D. 15

E. 6

19. Round 556.462 to the nearest tens place

A. 556.46

B. 556.5

C. 556

D. 560

E. 600

20. What is the median of these numbers: 6, 2, 5, 3, 6, 9

A. 6

B. 5

C. 5.17

D. 5.5

E. 4

21. $\frac{530}{5}$ equals

A. 53

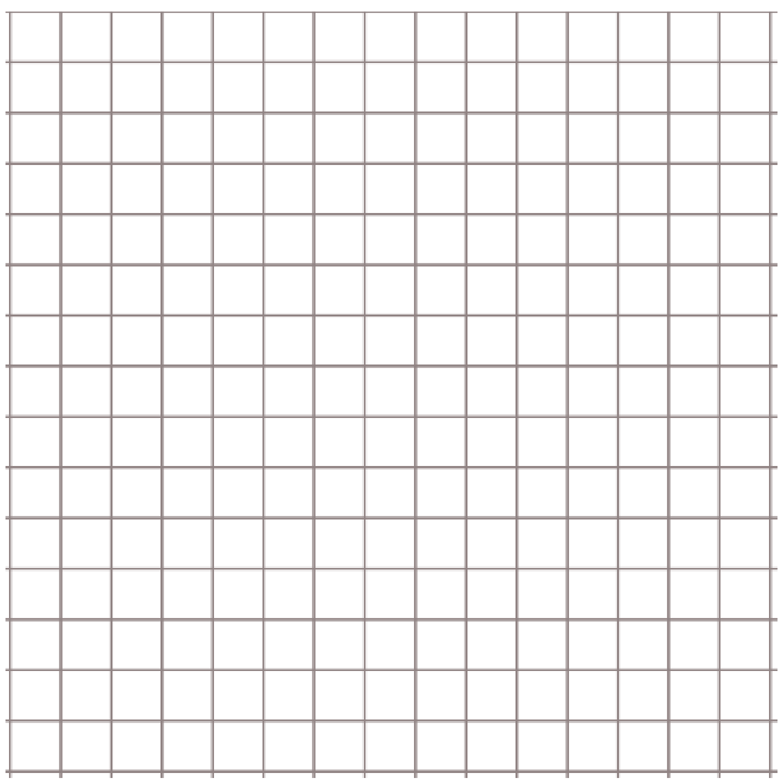
B. 130

C. 160

D. 16

E. 106

22. Plot the Following TWO Points on the Grid below: (0, 0) and (-3, 1)



Please Identify, Check or Circle Your Answer for Each One of the Following:

23. Your Current (K-12) Grade level: _______________

24. Your current Age: ________________

25. Gender: ____Male ____Female

26. Ethnicity: ____White ____Pacific Islander ____Hispanic _____Other

____ Asian ____ Native American ____Black/African American

27. In what state is your school located in? _________________________

28. I am currently taking the following mathematics class(es): __________________________

29. I can use a calculator in my mathematics class during classwork and instruction.

____Strongly Agree ____Agree ____Disagree ____Strongly Disagree

30. If I do not have a calculator, one is provided for me in my mathematics class.

____Strongly Agree ____Agree ____Disagree ____Strongly Disagree

31. I am confident in my understanding of my mathematics coursework.

____Strongly Agree ____Agree ____Disagree ____Strongly Disagree

32. I feel comfortable asking questions in my mathematics class.

____Strongly Agree ____Agree ____Disagree ____Strongly Disagree

33. I can use a calculator for my mathematics exams.

____Always ____Sometimes ____Hardly Ever ____Never

34. "I believe that I need to use a calculator in my mathematics class." Please explain why or why not below: ____

____

____

Appendix B

Semi-Structured Interview Questions (Qualitative)

1. Describe the ability of your students to perform *fundamental mathematical skills, without calculator usage.
2. How did your students acquire these fundamental mathematical skills?
3. If your students have trouble demonstrating fundamental mathematical skills without a calculator, what strategies or techniques, if any, do you believe ultimately improve fundamental mathematical skills?
4. Are there parameters or limits for calculator usage in your classroom? For example: calculators permitted on exams or not permitted during in class coursework instruction.
5. Please describe your journey to becoming a mathematics teacher at your school.

* Fundamental Mathematical Skills – These are the primary skills according to the Common Core State Standards (CCSS) that students are required to know. These mathematics skills are expected to be taught and reinforced in progression from K-7th grade. These skills include the introduction of the following concepts with a focus on the ability to: perform addition, subtraction, problem solve and identify place value as well as begin operations and algebraic thinking (grades K-2), perform multiplication and division, measurement and geometry, understand number operation in base ten and fractions (grades 3-5), ratios and proportional relationships, early expressions and equations, calculation of rational numbers, statistics and probability (grades 6-7), (Common Core State Standards Initiative, 2018).