The Effect of the TI-Nspire on Student Achievement in Common Core Algebra

Submitted by

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Abstract

This study investigated the relationship between Common Core Algebra (CCA) courses that do not use TI-Nspire technology to CCA courses that use TI-Nspire technology. To address the problem of the study and attempt to answer the research question by evaluating the hypothesis, this study used quazi-experimental research design. Two quantitative data instruments were used to investigate the variables: A pretest was used to determine if all participants in the study were not at an advantage due to prior mathematical knowledge. A posttest was used to determine if there was a difference of the mean scores of the control and treatment groups. The population of the study was ninth grade students in a public high school who were enrolled in CCA. The major findings noted that the means of the pretest scores were statistically equivalent while the means of the posttest score were statistically different. The findings suggest the use of TI-Nspire technology in CCA classrooms is, in fact, a benefit to students. It further recommends the study be replicated with a larger student population and sample size within an expanded geographical area.

Dedication

To my late parents, Michael and Ann, for their support and belief in me and what possibilities I could accomplish. My mother always saw the potential inside of me, even though I could not see it for myself. She constantly pushed me to strive for the very best, and not to settle for any less than what I was capable of. Her foresight from years ago led me on this quest for a doctorate. My father worked very hard, days and nights, only in hopes of his children living a better life than he. He believed in education as a top priority, as it was an investment in you. This belief motivated me to continue my education far beyond my undergraduate coursework. For instilling these beliefs in me, I dedicate this accomplishment to you. I love you and miss you both very much.

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Closer to home, I would like to thank friends who are like family, Nestor Ibanez and Camille Birmelin, who inspire me.

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Chapter 1: Introduction to the Study

Introduction

On a daily basis, technology is a continuous part of our health, learning, communication, work and mobile life. It is difficult to imagine what would happen if we had to go without the technological innovations that have changed our culture and that of the world's. In the world of education, it is not uncommon today to find teachers using technology in mathematics classrooms.

In New York State the Common Core Algebra Regents Exam, the Common Core Geometry Regents Exam, and the Algebra 2 Trigonometry Regents Exam require the use of a graphing calculator. Preparing our students for an unknown future and incorporating 21st century skills requires educators use the best available technology for student success (Sheehy, 2013). These 21st century skills include learning and innovation skills such as creativity and innovation, critical thinking and problem solving, and communication and collaboration (Partnership for 21st Century Skills, 2007). The TI-Nspire interactive graphing calculator technology, created by Texas Instruments, enables students to model algebra in ways a traditional graphing calculator cannot. Teachers can also use the TI-Nspire effectively in "flipped" lessons (Tucker, 2012), where the student is sent home with a TI-Nspire activity to be completed at home, then discussed the next day in class.

The TI-Nspire requires teacher training and purchase of equipment. In a difficult economic climate, this is a challenge for many school districts. Time and money do not always result in student's better understanding complex algebra.

As our schools are preparing students for an unknown future, implementing 21st century skills are imperative for the success of our students. The TI-Nspire is one step beyond traditional graphing calculators. It enables students to model algebra to learn “how” and “why” it works. But, the question remains, does this impact student achievement as measured by benchmark test scores? Studies have been conducted analyzing the use of the graphing calculator in geometry courses (Khoju, Jaciw, Miller, 2005), but few exist that connect the same device to the algebra classroom.

Background of the Study

It is important to consider the amount of money school districts spend during this time of economic crisis. Schools have a limited budget and must spend it wisely. The purpose of this quantitative experimental research study is to examine the effect of a TI-Nspire graphing calculator on student achievement in high school Common Core Algebra (CCA) classrooms. This is of particular importance in New York State where all Mathematics Regents Exams require the use of a graphing calculator.

TI-Nspire calculators require teacher training and purchase of equipment. Both of these assets come at a cost to school districts. In a difficult economic climate, this is a challenge for many. Time and money do not always result in student’s better understanding complex algebra. There are few evidence-based studies that connect the use of the TI-Nspire to student achievement (Khoju, Jaciw, Miller, 2005). Therefore, it is of the utmost importance that educational research be done to note if the use of the TI-Nspire technology leads to greater levels of student achievement in the CCA classroom. This study would be a cost-effective way for school districts to determine the effectiveness of the TI-Nspire before making the financial commitment during this economic crisis.

Students must conceptually understand Algebra to be successful in CCA. Prior to the introduction of the Common Core State Standards (CCSS), students enrolled in algebra courses learned by rote memorization. This is no longer the case. One strategy teachers can use to teach mathematics in a way students can conceptually understand is by using graphing calculators equipped with TI-Nspire calculators. This allows students to see and manipulate algebra. The TI-Nspire is a step beyond traditional graphing calculators.

The 2013-14 school year was the first year of the CCA administration in New York State. The New York State CCA Regents Exam is a standardized exam accompanied by the CCSS implementation. Teachers throughout New York State spent most of the 2012-13 school year planning and preparing for the transition from the 2005 New York State Standards to the new CCSS. The New York State Education Department specifically refers to the Texas Instruments TI-Nspire graphing calculator in the modules modeling CCSS algebra mathematics for the teachers. This referral by New York State encourages more in-depth research about the TI-Nspire because it is not required for the CCA course and the CCA Regents Exam. This will be analyzed throughout this study.

To prepare for this shift, teachers of the Great Neck Public Schools (GNPS) who taught CCA attended training sessions provided by Texas Instruments that allowed them to infuse TI-Nspire calculator technology into the new CCSS algebra curriculum. Not all algebra classes were equipped with this technology. GNPS piloted a program during the 2012-13 school year that provided the opportunity to produce evidence and help determine if this technology would be best for all of the classes teaching the new algebra curriculum.

Problem Statement

It is not known how, or to what extent, the TI-Nspire impacts student understanding in CCA classrooms. The TI-Nspire is permitted on all New York State Mathematics Regents exams, the SAT, the ACT, and all IB exams. The SAT, ACT, and IB exams are not required for high school graduation in New York State, but the Regents exams are. The first mathematics Regents exam students take in New York State public schools is the CCA Regents Exam. For students to move onto higher math courses, they need to be fluent in the topics they have been taught. Conceptual understanding of topics supports this mathematical fluency. The TI-Nspire supports conceptual understanding of mathematics topics. Before school districts invest in TI-Nspire technology, it is necessary to understand what effect (if any) the technology impacts instruction and results in CCA by way of valid research.

As mentioned in this chapter, studies have been conducted analyzing the use of a graphing calculator to other courses. One example is a quantitative study by Hollar and Norwood (1999) analyzing the effectiveness of the graphing calculator. Another example is a quantitative study by Doerr and Zangor (2000) that discussed the role of the graphing calculator in the Calculus classroom. Few studies exist linking their effectiveness towards CCA courses. Therefore a study to determine if the TI-Nspire has an effect on CCA courses is both original and necessary.

Purpose of the Study

The purpose of this quantitative experimental research was to compare CCA courses that do not use TI-Nspire technology (independent variable) to CCA courses that use TI-Nspire technology (dependent variable) for CCA students at Great Neck Schools. To isolate teacher impact, teachers participating in the study were randomly selected and taught two sections of CCA. Teachers used one of the sections with the TI-Nspire and the other section will be taught without. Three teachers were used in total, providing six sections of CCA courses for this study. The CCA courses that do not use TI-Nspire technology (independent variable) were defined as three sections of 9th grade CCA courses that used traditional instructional strategies (control group). The CCARE courses that used TI-Nspire technology (dependent variable) were defined as three sections of CCA courses that utilize TI-Nspire technology as an alternative to traditional instructional strategies (experiment group).

Students in both the control and experiment groups took two Algebra tests designed by a textbook publisher. Benchmark testing occurred before and after the TI-Nspire intervention. Two data points were used in total; one pretest and one posttest.

The student scores on the posttest were used to establish the effect of the TI-Nspire (on the experiment versus the control groups). Because the CCA Regents Exam has been aligned to the common core state assessments for only a year, past scores were not used for comparison and were not used for this study.

This study contributed to the field of mathematics instruction by examining what effect (if any) the TI-Nspire has on CCA courses. Though the TI-Nspire is permitted on the SAT, ACT, and all NYSED mathematics Regents exams, it is unknown if the use of this technology impacts instruction.

Research Questions and Hypotheses

The first administration of the CCA Regents Exam was given in June of 2014. This does not allow this study to compare the results of this exam to prior administrations of this exam. To collect quantitative data for this study, publisher-created pre and posttests aligned to the CCA courses were used. Two benchmark tests were given to both the control group and experiment group to determine what effect (if any) the TI-Nspire has on student achievement in CCA courses. The two benchmark tests are: (1) the pretest and (2) the posttest.

Student scores in both groups were compared to determine the difference in passing (a score of 65%) and mastery (a score of 85%). The same data was used to perform an item analysis to determine if the TI-Nspire impacted scores on specific types of questions and topics. The following research questions and hypotheses guide this study:

R1: What, if any, is the effect of using TI-Nspire technology in CCA courses as measured by overall student CCA benchmark test scores?

R2: Does use of TI-Nspire technology create higher scores on certain questions/topics (via item analysis and topic review analysis)? The specific topics are: (1) interpreting functions, (2) building function, and (3) reasoning with equations and inequalities.

The research questions above seek to determine if the below hypotheses are verified as true or false.

H_1: There is not a relationship between students utilizing TI-Nspire technology in CCA courses and scores on the CCA benchmark tests.

H_0: There is not a relationship between the use of TI-Nspire technology and student performance on CCA questions/topics (as measured by the benchmark tests for the specified topics of (1) interpreting functions, (2) building function, and (3) reasoning with equations and inequalities.

Advancing Scientific Knowledge

Studies exist on the use of graphing calculators in the high school geometry classroom, but few exist examining the use of graphing calculators in the high school algebra classroom. Several studies have shown that calculators can be a positive contribution to the mathematics classroom. Students' problem solving skills can improve when calculators were used as a part of mathematics instruction (Ellington, 2003). The research of Hembree and Dessart (1986) showed that students improved their problem solving skills while using a calculator. In addtion to improving problem solving skills, the use of the calculator in the mathematics classroom helps students to have a more positive attitude towards the subject of mathematics (Hennessy, Fung, & Scanlon, 2001). Hollar and Norwood (1999) compared students who learned functions with a graphing calculator versus students who learned via traditional methods. The study showed that students who learned using the graphing calculator were more proficient utilizing multiple representations of the functions in the form of equations, tables and graphs. Understanding "how" and "why" the graphing calculators can be used to provide educators information "where" and "when" graphing calculators can be used in the algebra curriculum.

This study specifically addresses the lack of studies conducted examining the use of graphing calculators in the high school algebra classroom. This quantitative study revealed data to address this "need".

Significance of the Study

In this study, I seek to describe how the TI-Nspire graphing calculator technology influences student learning in CCA courses. The results of this quantitative, classroom-based study examined (1) the specific activities used with the TI-Nspire graphing calculator technology (as opposed to traditional graphing calculators) and (2) the frequency in which the teachers used the TI-Nspire graphing calculator technology within the CCA classroom.

Potential results could link the frequency of use of the TI-Nspire within the CCA classroom to improved scores on the posttest. Looking deeper, some constraints of the TI-Nspire graphing calculator technology may emerge within the classroom practice. Doerr and Zangor (2000) discussed the meaning and the role of the interactive graphing calculator within the pre-calculus classroom. They specifically examined how students used graphing calculators to support their learning of mathematics. Their study also examined the students' knowledge and beliefs using the graphing calculator within pre-calculus. Hollar and Norwood (1999) compared groups of students who used graphing calculators (not TI-Nspire) in the Algebra classroom (not Common Core) versus students who did not. They found that students in the graphing-approach classes demonstrated a level of understanding of the functions topic that was significantly better than students in the traditional Algebra class. This study produced similar findings, however it utilized TI-Nspire technology aligned to the CCA Curriculum.

Rationale for Methodology

This study examined student benchmark scores in CCA courses, frequency of teacher use of the TI-Nspire, and an item-analysis of topics from the benchmark scores. All of this data is quantitative and naturally lends itself to a quantitative study. The research question states, "What, if any, is the effect of using TI-Nspire technology in CCA courses as measured by overall student CCA benchmark test scores?" This research question specifically refers to the variables being analyzed.

Hollar and Norwood (1999) compared groups of students who used graphing calculators (not TI-Nspire) in the Algebra classroom (not Common Core) versus students who did not. This research was quantitative by design and compared the results of a control with an experimental group. Khoju, Jaciw, and Miller (2005) performed a systematic review of graphing calculator effectiveness K-12. This study also utilized a quantitative research design.

Nature of the Research Design for the Study

This study used data from six sections of Common Core Algebra classes (9th grade high school). Three of these sections used traditional graphing calculators while the other three sections used TI-Nspire technology. Students were placed into each section via a stratified sampling method. This technique was used because it has a higher statistical precision as compared with random sampling (Explorable.com, 2009). This is because there is less variability between each subgroup when dealing with the entire population.

Students took a series of Algebra exams designed by a textbook publisher. Benchmark testing occurred before and after the TI-Nspire intervention. Two data points were used in total: One pretest and one posttest. In addition to the benchmark testing, teachers were surveyed and observed to determine how frequently they use the TI-Nspire within the Algebra classroom. This was ongoing through the pretest and posttest period.

The student scores on the posttest were used to establish the effect (if any) of TI-Nspire technology (on the treatment versus the control groups). Because the New York State Regents was aligned to the CCSS for the first time in June of 2014, prior year scores were not used for this study.

Definition of Terms

Definitions for the key terms used in this study follow:

Graphing Calculator (GC): a calculator that has a 2.5 by 1.5 display screen with advanced features such as graphing, gable, solving matrices, statistical packages, and the like, in addition to other numerical operations (2008, Nasari, p. 11).

TI-Nspire: an interactive graphing calculator manufactured by Texas Instruments.

Computer Algebra Software: a computer program that is run by a computer or built into a graphing calculator having the capability to do algebraic operations symbolically (2008, Nasari, p. 11).

Common Core Algebra (CCA): an algebra exam designed for students in grade 9 who are enrolled in algebra courses in New York State.

Analysis of Variance (ANOVA): a statistical technique used in determining whether samples from two or more groups come from a population with equal means. Analysis of variance employs on dependent measure whereas multivariate analysis of variance compares samples based on two or more dependent variables (Hair et al., 1998).

Analysis of Variance (MANOVA): an extension of ANOVA to accommodate more than one dependent variable (multivariate). It is a dependent technique that measures the differences for two or more metric dependent variables on a set of categorical variables acting as independent variables (Hair et al., 1998) (Laerd Statistics, n.d.).

Assumptions, Limitations, Delimitations

The following assumptions were present in this study:

1. It was assumed that the teacher participants in this study were not deceptive with their answers. It is also assumed that the teacher participants answered questions honestly and to the best of their knowledge.
2. It was assumed that students answered benchmark questions to the best of their ability. Students did not haphazardly respond to the benchmark questions. It was assumed that students used the knowledge taught to them in the CCA classrooms and not answered questions randomly.

The following delimitations were present in this study:

1. The generalization of this study was limited to the students who enrolled in the CCA course described here. Students who were not enrolled in the CCA course were not included in the study.
2. This study was conducted at both High Schools in the Great Neck Public Schools. Both High Schools in the Great Neck Public Schools offer the same curricula and are

located within the same demographic region. Therefore, generalizations of this study were limited to sections of CCA taught at those schools.

The following limitations were present in this study:

3. Communication between the students in the experiment and control groups cannot be controlled. There was a possibility that students from different sections could communicate with each other and share instructional materials and methods between the experiment and control groups.
4. Students learn how to use the TI-Nspire as they are being used within the classroom. There was no formal student training to use the TI-Nspire technology.
5. Students in both the control and treatment groups received calculators that look similar, but function different. Students in the control group used TI-Nspire calculators with the TI-84 keypad. This maintains the appearance of a TI-Nspire, but the functionality of a traditional TI-84 graphing calculator. Students in the treatment group used the TI-Nspire calculator with the TI-Nspire keypad. This provided the TI-Nspire technology functions. The figure below shows how the TI-Nspire can be used as a traditional graphing calculator and with TI-Nspire functions based on the interchangeable keypad.

Figure 1.1. Displaying the interchangeable keypads of the TI-Nspire (Texas Instruments, n.d.).

Summary and Organization of the Remainder of the Study

Students taking algebra in New York State are required to take the CCA Regents Exam as a high school graduation requirement. One tool that is permitted on the CCA Regents Exam is the interactive graphing calculator. While researchers such as Hollar and Norwood (1999) and Doerr and Zangor (2000) have made connections to interactive graphing calculators and academic success, few studies exist that examine their success in courses related to the CCA curriculum.

This study required a control and experiment group. The control group used traditional methods of CCA instruction. This included the use of a TI-84 keypad used on the TI-Nspire calculator body. Other traditional methods included teaching students concrete formulas first, then going to abstract means. The experiment group utilized TI-Nspire technology to enrich instruction. This allowed teachers to teach abstractly first, then through conceptual learning students developed their own concrete ideas. The pretest and posttest were used to compare the differences (if any) between the two groups. The pretest and posttest provided quantitative data, allowing a quantitative methodology for this study.

Chapter 2 of this study reviews the current research of graphing calculator technology and academic achievement. Chapter 3 deeply describes the rational for the selected quantitative research methodology, as well as the design of the research to be conducted. This includes how the data will be collected, as well as procedures for maintaining a moral and ethical study. Chapter 4 analyzes how methodology from chapter 3 was applied to the collected data. This includes the results of the analyzed data and the results of the calculations. Chapter 5 addresses the conclusions, implications (theoretical, practical and future) and the recommendations (for future research and for practice.

Chapter 2: Literature Review

Introduction to the Chapter and Background of the Problem

The world we live in has become a digital world and classrooms have followed suit (McCoog, 2007). Students of today have grown up with cell phones, computers, and digital audio players as a functional and social part of their upbringing. There is at least one computer in most homes in the United States (Hikmet, Taylor, Davis, 2008). This should be an indication of how technology can be an integral part of the life of a student and should be used in the classroom. As educators struggle to gain the attention of students, we turn to the instructional use of technology for student achievement. Districts across the United States are increasing their spending on instructional technology because they believe in the correlation between the use of technology and an increase in student achievement (Schaidle, 1999; Hikmet et al., 2008). They are quick to jump onto the technology bandwagon without knowing if or how well technology actually effects student achievement (Schaidle, 1999).

Currently it is not known if there is a correlation with the TI-Nspire and student success in the CCA classroom. It is known that the TI-Nspire is permitted on the New York CCA Regents Exam, as well as the New York Common Core Geometry Regents Exam, the New York Algebra 2 / Trigonometry Regents exam, the SAT, the ACT, and all IB exams. Because the New York CCA Regents Exam is required for graduation from High Schools in New York State, it is important to understand if the TI-Nspire (that is permitted, but not required) is a tool for student success on the exam.

This chapter includes the theoretical foundations and the conceptual framework of this research study, describing the model that provides the foundation for this research study. Following this section is the literature review. The review of the current research identified the following themes associated with the use of the TI-Nspire calculator. Each theme is listed as a subsection of the literature review. The first theme to appear was the conceptual understanding of mathematics, followed by the use of technology in the mathematics classroom, then the development of curriculum, followed by the necessary pedagogy, and finally the teacher professional learning.

Theoretical Foundations

The theoretical foundation for this study is based upon the didactic triangle that has the three elements of student-teacher-mathematics. An example of this foundation was discussed by Steinbring (2005). It is important to note that this model has been used in a variety of different ways dependent on the context and the theory of learning involved. In this study, the learning occurs through experiences that are governed by tools. These tools can be mental (communications and interactions), physical (measurement rulers and protractors), or symbolic (mathematical notation and symbols). Interactive graphing calculators such as the TI-Nspire have a special place within this toolset because they can be seen as all three individual tools.

Each leg of the didactic triangle can be interpreted in more than one way. Persson explained:

> The three pillars of the didactic triangle can be interpreted with a double meaning, both as the learning processes, where teacher and the learners interact around the subject matter, and as the individuals and the subject matter with the learning outcomes that are involved in the educational situation. (2011, p. 8)

Persson’s (2011) didactic triangle is shown below in figure 2.1.

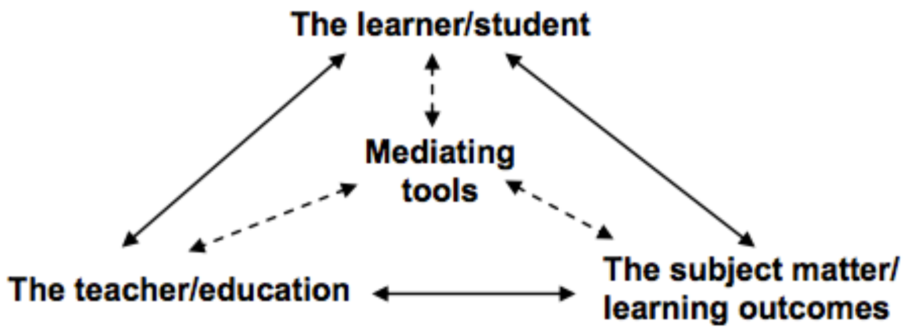

Figure 2.1. The didactic triangle with mediating tools as facilitators (Persson, 2011)

Brousseau (1997) developed the theory of didactical situations that examined the structure and process of the mathematical learning-teaching process over the different phases. This analysis included the use of calculators as tools for calculating, teaching, and learning. When students use calculators to make calculations, the calculators are calculating tools. When teachers use the calculator to develop concepts and procedures with students, the calculator becomes a teaching tool. Lastly, when students use calculators to facilitate discovery learning, or to explore mathematical functions, the calculator becomes a learning tool.

Persson (2011) further examined the process of the calculator being used as a tool, to a learning instrument. This is illustrated by figure 2.2. Persson reported:

> A tool can develop into a useful instrument in a learning process called instrumental genesis (Guin & Trouche, 1999, Laborde et al., 2005), which has two closely interconnected components; instrumentalization, directed toward the artifact, and instrumentation, directed toward the subject, the student. These processes require time and effort from the user. He/she must develop skills for recognizing the tasks in which the instrument can be used and must then perform

> these tasks with the tool. For this, the user must develop instrumented action schemes that consist of a technical part and a mental part. (2011, p. 8)

The instrumentation process does not include mathematics learning or mathematics curriculum. The teacher remains the key role of guiding the learning in the mathematics classroom by using social construction as a part of the classroom community (Mariotti, 2002). The instrument, in this study, is the TI-Nspire interactive graphing calculator.

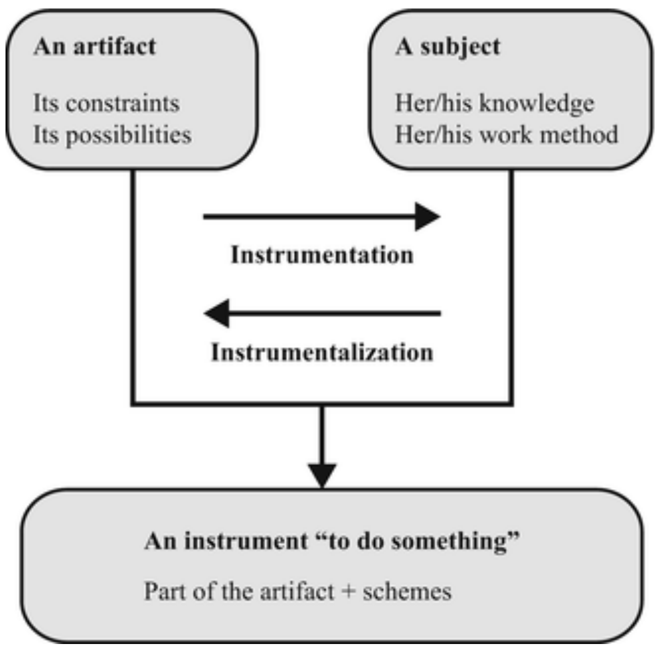

Figure 2.2. From artifact to instrument (Trouche, 2005)

Conceptual Framework

Dick and Burrill (2009) discussed a framework of mathematics teaching and learning. Based on this framework, there were four principles that emerged, they are:

1. Curricular importance
2. Cognitive demand
3. Action-consequence
4. Reflection and sense-making

These principles help inform instruction using the TI-Nspire in the Algebra classroom. Dick and Burrill said this about the mathematics principles and the TI-Nspire:

> The principles are decidedly not technology- or pedagogy-neutral; they are prescriptive design principles for an instructional strategy using TI-Nspire. They reflect a set of values and assumptions regarding the needs of students and teachers to improve their mathematics learning and teaching, with a clear eye toward exploiting the special affordances of the TI-Nspire technology. The principles make explicit suggestions regarding which content should be targeted, what kind of activities students should engage in around that content, and how and where in the instructional strategy TI-Nspire should be used in supporting or facilitating those activities. The principles guide curriculum content authors in producing both electronic and hard copy materials which combine to provide practical solutions to these important tough to teach/tough to learn topics. (2009, p. 13)

Curricular Importance

When selecting topics to teach using the TI-Nspire Dick and Burrill (2009) suggested, “choose topics of fundamental importance in school mathematics curricula” (p.14). As noted throughout this chapter, sometimes teachers use technology for the sake of using technology. Dick and Burrill (2009) note that it is necessary to use the technology by helping students to engage with those major ideas that appear over and over again at different grade levels throughout the mathematics curricula (p.14). This directly relates to the section of the literature review associated with curriculum. Just as it is important to match a textbook or ancillary publication to the curriculum, it is just as important to connect the technology to the big ideas of the mathematics curriculum (Dick & Burrill, Tough to teach/tough to learn: Research basis, framework, and principles for a practical application of TI-Nspire™ Technology in the Math Nspired series, 2009).

Cognitive Demand

When selecting activities for use with the TI-Nspire, Dick and Burrill (2009) suggested, activities should include inquiry tasks of high cognitive demand (p. 14). Teachers can engage students in low-level cognitive demands and in high-level cognitive demands (Stein, Smith, Henningsen, & Silver, 2000). The low-level cognitive demands can be classified as memorization tasks and procedures without connections tasks. The high-level cognitive demands can be classified as procedures with connections tasks and doing mathematics tasks.

Memorization tasks involve using a student's rote memorization (Stein, Smith, Henningsen, & Silver, 2000). This allows students to draw upon prior knowledge such as formulas, definitions, rules, and definitions from their own memory. The memorization tasks cannot be solved using steps or a procedure. This is because the steps or procedure does not exist or because the task is too short to require a procedure. Memorization tasks are not unique because they involve students to reproduce their work exactly the way it was learned. Memorization tasks are simple and have no connection to the learning that is reproduced.

Procedures without connections tasks deal specifically with algorithims (Stein, Smith, Henningsen, & Silver, 2000). There is as required procedure that is learned from previous lessons or learning experiences. These procedures required limited cognitive demand to be completed successfully. They are similar to the memorization tasks because they also do not connect to the underlying meaning of the procedures being used. The procedures are geared towards finding the correct answer instead of developing conceptual mathematical understanding. They also do not require explanations, any explanation used would only focus on the actual procedure being used.

Procedures with connections tasks draw on procedures to develop a deep conceptual understanding of the student (Stein, Smith, Henningsen, & Silver, 2000). This allows students to foster a deep understanding of mathematical concepts and ideas. These procedures also provide broad general procedures that are closely aligned to the mathematics concept being taught. This is opposed to using a specific algorithm that do not require deep thought. The procedures with connections tasks can express a mathematical concept in multiple ways including visually (diagrams), physically (manipulatives), and problem solving simulations. These connections between multiple representations establish mathematical meaning. They also require students to use cognitive effort. While general procedures can be followed, they need to be followed with purpose. Then, students can use the deep conceptual ideas that support the procedures in order not only understand the task, but complete it as well.

Doing mathematics tasks require students use complex, non-algorithmic thinking that is not rehearsed or explicitly suggesed by the task (Stein, Smith, Henningsen, & Silver, 2000). Students are further challenged to understand and explore the concepts, processes, and relationships that exist within mathematics. This requires students to self-regulate and self-monitor their own cognitive process as they utilize relevant knowledge while working through the task at hand. Doing mathematics tasks require students to use a great amouth of cognitive effort and unpredictable by nature as students participate in the solution process.

Action-Consequence

When establishing an environment for TI-Nspire use, Dick and Burrill (2009) recommended, “a TI-Nspire document should provide an environment for students to deliberately take mathematically meaningful actions on objects and to immediately see the mathematically meaningful consequences of those actions" (p. 18). Dick (2008) discussed the connections of how students learn mathematics when he said:

> Students learn mathematics by taking mathematical actions (e.g., transforming, representing, manipulating) on mathematical objects (e.g., symbolic expressions, graphs, geometrical figures, physical models), observing the mathematical consequences of those actions, and reflecting on their meanings. Students' reflections on mathematical consequences of mathematical actions on mathematical objects are the fuel for feeding the cycle of prediction–conjecture–testing that ultimately leads to proofs or refutations. (p. 334)

Dick and Burrill (2009) also discussed the visual proximity and immediacy as linked to action-consequence. The TI-Nspire (along with other graphing calculators) gives students an opportunity to have their work in close visual proximity (handheld technology) while receiving immediate feedback based upon their interactions with the calculator. This reduces the space and time between the actions and consequences, similar to how students receive immediate consequences (scores) to their actions (control input) as they play video games. The reduction of proximity and immediacy of feedback allows "students working on TI-Nspire should immediately see the mathematically meaningful consequences of the deliberate and mathematically meaningful actions they perform" (Dick & Burrill, 2009, p. 20).

Reflection and Sense-Making

When designing learning activities on the TI-Nspire, Dick and Burrill (2009) recommended, "learning activities build around TI-Nspire action-consequence documents must explicitly promote student reflection – especially the posing of questions for sense-making and reasoning (including explanation and justification)" (p. 23). Reflection and sense-making are driven by effective questioning strategies. Effective questioning strategies are driven by good inquiry questions. These questions are purposefully designed by teachers through the lesson planning process and executed within the classroom. A good inquiry question is often embedded within a high-level mathematical task (Dick & Burrill, 2009).

The TI-Nspire can be interpreted as a mediating tool from the didactic triangle (Persson, 2011) as a starting poing, and then, through the four principals of teaching mathematics (Dick & Burrill, 2009), incorporated as an instrument in the classroom from artifact to instrument (Trouche, 2005). This framework is illustrated in figure 2.3 below. This shows how the study will use the calculator as a mediating tool, incorporate it into the classroom through four different theories of learning, and be analyzed as an instrument for student achievement.

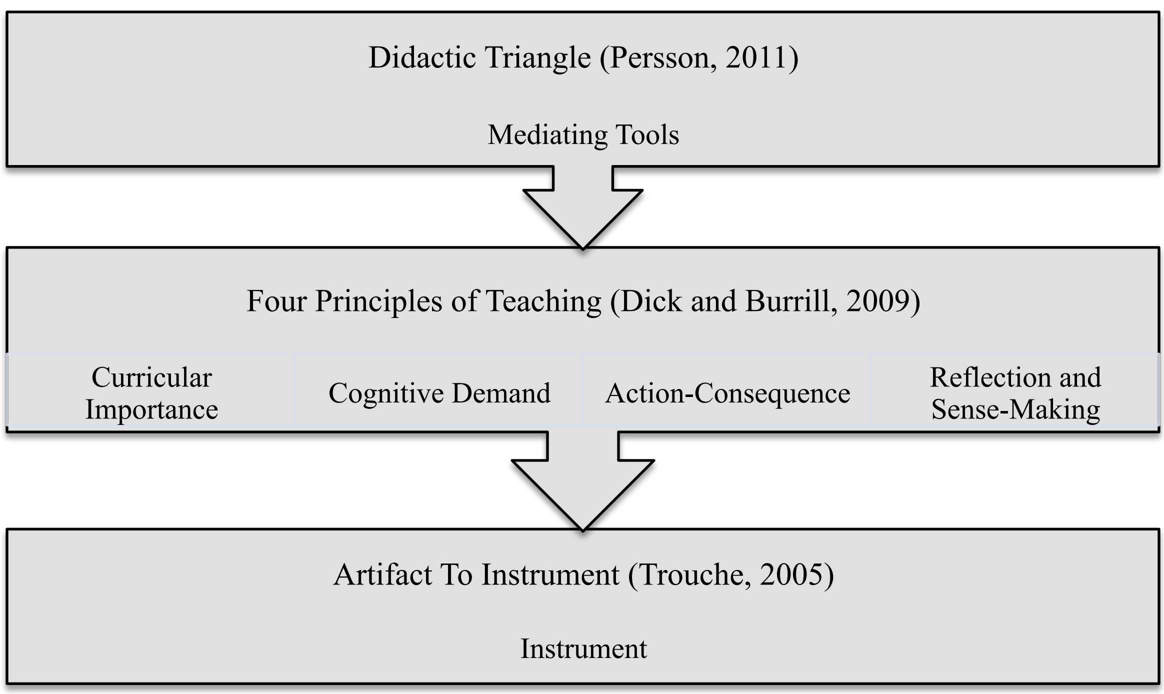

Figure 2.3. Diagram of framework

Literature Review

As we continue to shift our focus from contemporary methods of teaching to using technology-based lessons in the classrooms, it is important to consider the theories of educators who have been successful in this change. There are many different theories, practices, and guiding principles that teachers have used for years that need to be considered when planning technology integration for the future (Dawson and Dana, 2007). When technology is implemented into the classroom, teachers do not always immediately utilize the technology they are given. It is impossible to even focus on student achievement until teachers begin to use the technological resource for their lessons. To significantly impact the degree of student success in the technology classroom, teacher pedagogy must be addressed and traditional methods of teaching should be considered (Zhao, Pugh, Sheldon, Byers, 2002). While these factors have been used in education for quite some time, new research has dictated that these factors can be used to help improve education with technology. A study has discussed the factors in detail and how the factors relate to one another and their use in the classroom (Zhao, et al., 2002).

In a traditional high school algebra class, students can compute the slope of a line using a formula, then graph functions on graph paper. A teacher will facilitate a discussion to see if students can determine the relationship between these results. Some students see the relationship, while the majority of the class copies the rule that the teacher wrote on the chalkboard. The TI-Nspire technology enables students to graph a function, and then manipulate it using a touchpad and mouse to see how the slope variable changes with the steepness of the line. This process of manipulating the function leads to students being able to conceptually understand the relationship that is taught.

The Buckner study (2011) involves using TI-Nspire technology to teach the topic of functions to Algebra students. The results are encouraging and support to use of technology to teach the topic of functions. They used a two-group pretest-intervention-posttest quazi-experimental design, assessing students before and after the intervention of TI-Nspire technology to teach the topic of functions in the algebra classroom, NCTM, (National Council of Teachers of Mathematics, 2008). The assement used before and after the TI-Nspire implementation was created by the teachers of the school. This study shows that students can improve their conceptual understanding of functions by using TI-Nspire technology.

From the review of the literature, five emergent themes were discovered: (1) conceptual understanding of mathematics; (2) technology and mathematics; (3) curriculum; (4) pedagogy; and (5) teacher professional learning. Each of these themes are discussed in detail in the following subsections of this chapter. The idea of conceptual understanding of mathematics discusses how students learn mathematics by way of the mathematical concept. This differs from the process of students learning mathematics through rote memorization and practice. Next, use of technology in the mathematics classroom discusses how technology evolved to become an educational tool. This includes the use of computers and interactive graphing calculators such as the TI-Nspire within the mathematics classroom. Then, the section on curriculum discusses how the mathematics curriculum has evolved throughout the years into the CCSS. The section on pedagogy discusses how teachers use educational technology to support the CCSS within the mathematics classroom. And finally, the section on teacher professional learning discusses how teachers are trained to learn educational technology innovations for the success of students.

Conceptual Understanding of Mathematics

In 1980, newly elected President Ronald Reagan began to drastically reduce educational funding. This action forced organizations to find new ways to raise educational awareness (McLeod, 2003). Eventually, this led to a published report on the status of education in America in 1983. The National Commission on Excellence in Education's (NCEE) *A Nation at Risk* (ANAR) illustrated the academic underachievement of students from 1963 to 1980. The report eventually led to the creation of the NCTM Standards in 1989 (Hofmeister, 2004). These standards were later revised in April of 2000 and published as *Principles and Standards for School Mathematics* (PSSM). The PSSM can be written as six principles for school mathematics: (1) Equity. Excellence in mathematics education requires equity—high expectations and strong support for all students; (2) Curriculum. A curriculum is more than a collection of activities; it must be coherent, focused on important mathematics, and well articulated across the grades; (3) Teaching. Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well; (4) Learning. Students must learn mathematics with understanding, actively building new knowledge from experience and previous knowledge; (5) Assessment. Assessment should support the learning of important mathematics and furnish useful information to both teachers and students. These standards focused on problem solving strategies including conceptual understanding. The PSSM guides teacher to help improve students' school mathematics. They also provide mathematics goals for students in grades prekindergarten through grade twelve. The PSSM also help guide mathematics curriculum, teaching, and assessments. In addition to the resources they provide to teachers and students, the PSSM are also a resource for education leaders and policymakers to use to determine how to improve mathematics instructional programs. One strategy recommended by the PSSM to improve mathematics instruction is incorporating the use of educational technology within the mathematics classroom. This includes educational technology such has computer algebra software, dynamic geometry computer software, and interactive graphing calculators. The TI-Nspire incorporates all of these elements into one handheld device.

Technology and Mathematics

NCTM included the use of educational technology to help students conceptually understand topics in mathematics in its March 2008 position paper (National Council of Teachers of Mathematics, 2008). Specifically, NCTM explains that the technology within the mathematics classroom consisted of "graphing calculators and other technological tools, such as computer algebra systems, interactive geometry software, applets, spreadsheets, and interactive presentation devices" (p. 1). In addition to these items, the modern mathematics classroom can include iPads, computers, graphing calculators, and SMARTboards as instructional tools. These tools are not substitutes for good pedagogical practice within the classroom.

The modern-day student is very familiar with technology as well as technological changes and improvements. This natural gravitation of students towards technology paves the way for teachers to implement various forms of technology within the classroom (DePeau & Kalder, 2010). The use of technology can also motivate students to focus on the material being taught. It can also empower students to independently explore learning opportunities. This technology not only impacts what is taught, but how it is taught and how students will learn it (Beckmann, Senk, & Thompson, 1999). Specifically for mathematics, technology allows students to go far beyond what traditional books have to offer. Students can learn from interacting with multiple representations including graphs, tables, algebraic expressions, and geometric figures (Center for Technology in Learning, SRI International, 2006).

Technology cannot only be available, but it must be appropriately used in the mathematics classroom. The NCTM position paper specifically notes that the effective use of technology had the ability to make mathematics accessible to all students (National Council of Teachers of Mathematics, 2008). Still, it is important to note that technology alone is not the answer. Technology is not valuable unless it properly used for the success of all students. The technology becomes a learning tool when teachers effectively use it to enhance student learning. Technology alone will not eliminate the difficulties students have in mathematics (Hollebrands & Zbiek, 2004).

The educational technology of the graphing calculator have been widely adopted as cost-effective handheld device that is linked directly to the mathematics curriculum (Roschelle & Singleton, 2008). Roschelle and Singleton's (2008) research found that graphing calculators helped to increase the conceptual understanding of students as well as their problem solving approach. Their reasoning was the calculator eliminated the laborous task of computing numbers and students could focus on the task at hand.

Teachers have debated the use of a calculator in the mathematics classroom for years. There are teachers who permit free use of calculators during any component of instruction and others who limit the use for only very complex computations. Calculator use within the mathematics classroom can enhance instruction and foster conceptual understanding with students (National Council of Teachers of Mathematics, 2011). This fact does not make the mathematics any easier for students and calculator use has greatly impacted curriculum and instruction (Beckmann, Senk, & Thompson, 1999). The role of the calculator has shifted from making simple mathematics calculations to empowering students to represent mathematics in multiple ways and make unique connections (Roschelle & Singleton, 2008).

Some teachers used graphing calculator technology to make complex calculations easier. However, the lessons taught were not the focused on the graphing calculator as a piece of instructional technology. When the graphing calculator was added on to the lesson, rather than be the focus of it, it failed to improve learning (Kastberg & Leatham, 2005). Kastberg and Leatham

(2005) also found having the graphing calculator available for students not enough for academic success. Teachers needed to incorporate it as a key component of instruction otherwise students would not reap the benefits over traditional methods of instruction.

The Principles and Standards envisioned a mathematics classroom where students had access to technology that would facilitate student learning (National Council of Teachers of Mathematics, 2000). The NCTM (2000) continues to stress that the effective use of technology is the responsibility of the classroom teacher. As technology is deployed into the classroom, the role of the classroom teacher shifts. The teacher takes on a more interactive approach to teaching within the multimedia environment (Vogel & Klassen, 2001). Choi-Koh (2003) suggests that the implementation of educational technology also shifts the thinking process of students from “intuitive to operative, and then on to application" (p. 368).

Teaching mathematics with technology is a new and innovative way of both teaching and learning (Privateer, 1999). Privateer (1999) continues to say that instructional technology can be the catalyst for real change in pedagogy, specifically in the area of course content and delivery of instruction. Instructional technology can be considered a mathematical tool, an instructional tool, and may be regarded as a cultural tool (Galbraith, 2002). Mathematically, technology can increase the capacity of learning, an instructional tool that shifts the thinking of both the teacher and the students, and a cultural tool that changes how people interact with given tasks. The role of the calculator as an instructional technology device allows students to have a deeper conceptual understanding of mathematics while achieving higher levels within the mathematics classroom.

Teachers who use technology in their classrooms create learning outcomes that ultimately lead to technology being used across the curriculum (Privateer, 1999). Technology is rapidly changing and evolving, making it extremely difficult for educators to know what tools are just short term trends, and what tools are effective in the long run (Podlesni, 1999). When teachers use educational technology as a tool for learning, the questioning technique of the teacher must be altered so students do not just press a button and arrive at an answer (Choi-Koh, 2003). Choi-Koh (2003) explains that students need to be able to form relationships with the questions posed, and the result achieved. The students also must be focused on the objective of the lesson and not the technology tool that helps them to arrive at the answer (Burrill, 1998). Burrill (1998) also states that questions posed on assessments must be connected to the subject matter, not the technology being used to teach and assess it.

Choi-Koh (2003) discusses how little research exists about how technology can impact mathematical thinking and the learning environment. One research study by Hembree & Dessart (1986) provided a meta-analysis on the use of calculators in the mathematics classroom. Hembree & Dessart (1992) later conducted another meta-analysis regarding the research conducted on calculators in mathematics. While this shows that research has been conducted, it also opens the door for more research to be done.

Several studies have shown that calculators can be a positive contribution to the mathematics classroom. Students' problem solving skills can improve when calculators were used as a part of mathematics instruction (Ellington, 2003). The research of Hembree and Dessart (1986) showed that students improved their problem solving skills while using a calculator. In addtion to improving problem solving skills, the use of the calculator in the mathematics classroom helps students to have a more positive attitude towards the subject of mathematics (Hennessy, Fung, & Scanlon, 2001). Hollar and Norwood (1999) compared students who learned functions with a graphing calculator versus students who learned via traditional methods. The study showed that students who learned using the graphing calculator were more proficient utilizing multiple representations of the functions in the form of equations, tables and graphs.

Many classrooms today are equiped with interactive whiteboards such as the Promethian Board and the SMARTboard. These devices enable a teacher to present lessons that include multimedia such as photos and videos. The interactive whiteboards go beyond the traditional static PowerPoint presentations and allow the presenter to interact with the presentation as it is in use. This creates a more dynamic learning enviornment that is visually pleasing to the learner (Ball, 2003).

Texas Instruments has revolutionalized the use of calculator technology. Built in memory expanded the role of the calculator to run applications. The TI-83 was released in 1999 and provided graphing functionality. It had enough internal memory and processing power to not only run applications, but to allow the user to upgrade the operating system. Five years later, Texas Instruments released the TI-84. Compared to the TI-83, the TI-84 had three times the internal memory and twice the processing power. Texas Instruments further expanded the role of the calculator by adding a micro USB port to the TI-84 for fast connection to a computer or wireless hub. This enabled the calculators to receive application either from the computer, or wirelessly. Texas Instruments introduced the first generation of the TI-Nspire in 2007. The first generation TI-Nspire is called the “clickpad” because the keypad can be changed from a traditional TI-84 keypad to the new TI-Nspire keypad. Again, Texas Instruments changed the role of the calculator. Instead of the calculator running applications, it now had enough power and memory to create, share, and store documents. The latest version of the TI-Nspire, called the “clickpad” was introduced in 2010. This version allowed calculators to interact wirelessly with a computer via the TI-Navigator system. This enabled teachers to send and receive documents wirelessly, as well as have students display their calculator screens on an interactive whiteboard from the comfort of their desk.

Curriculum

As our students evolve and new technology is developed, curriculum writers must adapt to our global technological society. It is important that 21st century skills are included in curriculua as well as technology when it will enhance instruction. The 21st century skills include learning and innovation skills such as creativity and innovation, critical thinking and problem solving, and communication and collaboration (Partnership for 21st Century Skills, 2007). The Partnership for 21st Century Skills (2011) stated:

> Fusing a core subject like mathematics with 21st Century Skills makes teaching and learning more engaging, more relevant and more rigorous, ensuring that a greater number of students have an advanced level of understanding and ability in mathematics. Mathematics as a discipline offers its own unique set of knowledge, skills, and processes. It also offers the opportunity through an exploration of key math concepts to provide links from school-based learning to interdisciplinary themes that are essential to every student's ability to thrive as a global citizen. Math offers students a lens through which to distinctively view the world, and empowers students with tools for meaningful participation in our democracy and economy. Students are able to discover ways to solve old problems and develop new ways of thinking about the world around them – a skill that is essential to tackling the biggest challenges in our interconnected, global world. (p. 4)

Rotherham and Willingham (2009) identified that skills and knowledge are not separate. Students who do not have content knolwedge cannot effectively use thinking skills. Choi-Koh (2003) suggested that instructional interventions, such as technology, should be included within the curriculum to include higher order thinking and critical problem solving. Without including these interventions, students will not see the merit in multiple representation of a function, from a graphical solution to an equation (Choi-Koh, 2003). While this multiple representation is very impressive, it is important to note that the caluculator relies on the input from the user, in this case the student. It also cannot analyze and determine how to utilize the output the calculator produces (Reys & Arbaugh, 2001).

When considering incorporating calculator technology within the mathematics curriculum, it is important to understand how it is used. The United States and Portugal tend to have a high frequency of calculator use while Japan has a very low frequency of calculator use and indidicated by the Third International Mathematics and Science Study (TIMMS) (Tarr, Uekawa, Mittag, & Lennex, 2000). While graphing calculators are used most frequently in higher-level mathematics, such as Algebra 2, pre-calculus, and trigonometry, the scientific calculator remains the main calculator used within Algebra 1 and geometry classroom (Dion, Harvey, Jackson, Klag, Liu, & Wright, 2001).

In the years since the Dion, Harvey, Jackson, Klag, Liu, and Wright (2001) study, the Common Core State Standards Initative (CCSSI) has developed a set of standards that emphasize college and career readiness (2010). These standards have sparked a new Algebra mathematics curriculum for States participating in the CCSS. The CCSS include: (1) Make sense of problems and persevere in solving them; (2) Reason abstractly and quantitatively; (3) Construct viable arguments and critique the reasoning of others; (4) Model with mathematics; (5) Use appropriate tools strategically; (6) Attend to precision; (7) Look for and make use of structure; (8) Look for and express regularity in repeated reasoning. These standards of mathematics practice seek a balance of procedure and understanding. The TI-Nspire directly connects with these standards when used a strategic tool and aides students in attending to precision.

Pedagogy.

As we continue to shift our focus from contemporary methods of teaching to using technology based lessons in the classrooms, it is important to consider the theories of educators who have been successful in this change. There are many different theories, practices, and guiding principles that teachers have used for years that need to be considered when planning technology integration for the future (Dawson and Dana, 2007). When computers are put into classroom, teachers do not always immediately utilize the technology they are given. It is impossible to even focus on student achievement until teachers begin to use the technological resource for their lessons. To significantly impact the degree of student success in the technology classroom, teacher pedagogy must be addressed and traditional methods of teaching should be considered (Zhao, Pugh, Sheldon, Byers, 2002). While these factors have been used in education for quite some time, new research has dictated that these factors can be used to help improve education with technology.

Technology education implies that teachers should use computers everyday in their classroom lessons (Keller and Bichelmeyer, 2004). But how are teachers supposed to use technology effectively without having received relevant and practical training? Transforming the way teachers teach is no easy goal. Teachers must remember that the purpose of technology is to use it as a tool to support the standards based learning. If this is forgotten, students get lost in the fun of the technology and miss the seriousness of the lesson.

While the use of technology increases in the classrooms, state exams still remain on paper. Students are relying on writing using word processors, using spell check and grammatical checks to write. This actually decreases their ability to write an effective essay on paper state exams (Russell and Abrams, 2004). Teachers were surveyed and it was found that teachers are decreasing their instructional use of computers in the classroom because their state assessments are given on paper and not on the computer (Russell and Abrams, 2004). In this day an age of technology savvy students, not all students prefer using technology as an educational tool. Hikmet (2008) surveyed students in one high school and found that students do not have a preference to use technology over conventional methods when offered the choice.

State exams will continue to be administered on paper for now because urban schools have less access to computer technology than suburban schools (Russell and Abrams, 2004). This proves that while technology is widely used to increase student achievement, it is not always a preferred method of instruction among teachers and students. Also, even if teachers and students are to use technology as an instructional tool, it is not possible at this time to align it to a state assessment.

Teacher Professional Learning

Teachers are given technology and often they feel intimidated because students know more about it than they do (Schaidle, 1999). When teachers are trained in using classroom technology their training rarely transfers into the classroom (Glazer, Hannafin, Song, 2005). This is because the practical application of technology use a teacher is trained with stops the day the training stops. For the training to be effective, it needs to be continued on an ongoing basis. Teachers have difficulties integrating technology in the classroom because training does not reflect real classroom experiences (Dawson and Dana, 2007). Training is often done in perfect, unrealistic situations that do not reflect actual classroom environments. This causes teachers to become frustrated and give up on implementing technology before giving it a chance to work (Glazer et al., 2005).

If teachers were to study their own practices they could get a better idea how to incorporate technology in their classrooms (Dawson and Dana, 2007). This strategy is called teacher inquiry. Many professionals refer to teacher inquire as reflective practice. This is where teachers review how they teach, if it was effective, and what can be changed to improve future instruction. Teacher inquiry is used widely in general teaching and is now being sought after for technology integration.

Also, when teachers are not oriented on how to use technology appropriately, they tend to oversimplify technology and do not use it as effectively (Schaidle, 1999). This prevents students from using technology effectively; therefore it does not promote student achievement. Teachers, just like students, need hands-on opportunities to learn how to use technology effectively before they can incorporate it into their classrooms. Strategies introduced must reflect real world practices and those strategies need to be linked to the curriculum so it can be easily introduced into the current classroom environment. Different levels of technology instruction must be introduced so teachers are not intimidated by a strategy that is too complicated for them.

To further complicate issues, teachers are often expected to troubleshoot the educational technology in their classrooms to keep the momentum of the lessons. One district decided to take hardware and troubleshooting out of the equation (Sandholtz and Reilly, 2004). The district put curriculum first, giving educators the opportunity to be more productive more quickly. To accomplish this, the district outsourced their technology maintenance and troubleshooting to third-party contractors. This allows teachers be fully inventive with the use of technology in the classroom without worrying about troubleshooting faulty equipment. Overall, when teachers do not need to rely on technical skills, this will allow them to focus on curriculum and think of creative ways to implement curriculum using the technology. This, in turn, will provide better learning opportunities for students and their achievement.

To make the plan work, teachers who have mastered the technology integration need to be identified, and then these teachers should become mentors to other teachers who are not as proficient using technology (Glazer et al., 2005). Usually, teachers who mentor, have years of experience over those they are mentoring. In technology, the reverse is true. Teachers who are less experienced than more experienced teachers are often more flexible and knowledgeable when it comes to technology. More often than not, the teacher who has less experience in teaching has more experience in technology. That teacher then trains the teacher who has more experience in education but less experience with technology.

To prevent this aggravation with technology and teacher frustration, teachers must be provided with professional learning on a regular basis. Teachers need to be shown constructive, hands-on ideas that they can immediately infuse in their classroom environment. Development should include integrating technology applications in the lesson planning process, giving teachers a productive vision on how to accomplish their lesson objectives. Once teachers are properly trained, they should be supported with ongoing training. Fogarty and Pete (2010) discussed how teachers required sustained professional learning to support their learning objectives in the classroom. One strategy for ongoing professional learning of teachers is professional learning communities. Fogarty and Pete (2010) explained, “The promise of professional learning communities as problem-solving bodies for school improvement has been well-documented, but they need time, support, and structures to become effective” (p. 33). When these professional learning communities focus on the use of educational technology, they would further enrich the ways teachers use technology in their classrooms.

A technology coach should be provided to staff members (Schaidle, 1999). The coach would help mold the technology to the curriculum of each teacher and support the teacher as they implement it.

Another strategy the coach could use is team teaching. By having both an expert in subject content paired with an expert in technology education, lessons can be planned and incorporated that utilize the best of both worlds. This way, the talents of the subject teacher are used and the skills of the technology educator are used. This combined strength would produce excellent results and make teachers less reluctant to use technology in their classrooms.

Summary

This chapter first identified how our society has changed into a digital world, and how our classrooms have followed suit, explaining the background of the problem. The chapter then explains the purpose of this study is to determine if there is a correlation between the use of the TI-Nspire technology and student achievement in CCA. A pretest and a posttest will be used as an instrument to determine if this correlation exists.

The chapter then described the theoretical foundation for the study. This section discussed theories, principles, and practices that have been conventionally been used by teachers are now being infused with educational technology, such as the TI-Nspire. This section then discusses the use of the TI-Nspire as a technology tool within the Algebra classroom. The theoretical foundation is based upon the three elements of student-teacher-mathematics. The didactic triangle (figure 1), by Persson (2011), represents this relationship graphically. The TI-Nspire is the central part of this relationship and can grow from a tool into a learning instrument as illustrated by figure 2. The conceptual framework is based of Dick and Burrill's (2009) framework of mathematics teaching and learning. This is the conduit that connects figures 2.1 and 2.2 as illustrated by figure 2.3.

From the theoretical foundation, a didactic triangle is used to show the relationships between the student, teacher, and learning outcomes. The mediating tools, in this case, the TI-Nspire interactive graphing calculator, interconnect all of these relationships. The conceptual framework analyzes how the TI-Nspire acts as an instrument between a subject and their artifact.

From the review of the literature, five emergent themes were discovered: (1) conceptual understanding of mathematics; (2) technology and mathematics; (3) curriculum; (4) pedagogy; and (5) teacher professional learning. First, this chapter examined the idea of conceptual understanding being developed from ANAR that led to the NCTM standards. Second, this chapter discussed the use of technology within the mathematics classroom. This built upon the idea of teaching mathematics conceptually by using technology as a tool for understanding. Other education technology innovations were discussed including the discussion on how they were incorporated successfully into the classroom. This section referred back to the NCTM standards and how the use of the interactive graphing calculator contributed to the conceptual understanding of students in mathematics courses. Third, the impact of interactive calculators on curriculum was discussed. This included a focus on 21st century skills as well as student thought process. Calculator use was compared between different nations and different courses. This ultimately led to the creations of the CCSSI curriculum in mathematics. Fourth, the chapter discussed the pedagogy necessary for the paradigm shift necessary for teachers to adapt their instruction to meet the learning needs of the 21st century student. Last, the literature review addressed teacher professional learning. This section focused on what was necessary for teachers to be successfully trained to incorporate technology strategies within their own classrooms.

The literature review reveals that further research is necessary to determine if the TI-Nspire has an impact on student achievement in the high school CCA classroom. While research has been conducted on higher-level mathematics topics, no research currently exists analyzing the use of the TI-Nspire to the CCA classroom. This research study will analyze student achievement in CCA when the TI-Nspire is used as compared to CCA classes that used traditional methods. The methods of this research are noted in chapter 3.

Chapter 3: Methodology

Introduction

This chapter provides a detailed description of the research methodology and methods for conducting this quantitative study relevant to the research questions described in Chapter One. This chapter is divided into the following sections: (1) introduction; (2) statement of the problem; (3) research questions and hypotheses; (4) research methodology; (5) research design; (6) population and sample selection; (7) instrumentation; (8) study parameters; (9) research methodology; (10) instrumentation; (11) validity, (12) reliability; (13) data collection procedures; (14) data analysis procedures; (15) ethical considerations; (16) limitations, and (17) summary.

The purpose of this quantitative experimental research is to compare CCA courses that do not use TI-Nspire technology (independent variable) to CCA courses that used TI-Nspire technology (dependent variable) for CCA students at Great Neck Schools as measured by a pretest and a posttest. To isolate teacher impact, teachers participating in the study were randomly selected and each teaches two sections of CCA. Teachers only used the TI-Nspire with one of the sections and the other section was taught without the TI-Nspire. Three teachers were used in total, providing six sections of CCA courses for this study.

A passing score of 65% or greater in the CCA course is required by New York State for students to graduate high school. The study sought to determine the effect of student achievement in CCA courses that use TI-Nspire technology by comparing the experiment and control groups' scores on the pretest and the posttest. An item analysis of the benchmark tests was used to determine if the use of TI-Nspire technology enables students to score higher on certain topics within the CCA curriculum.

Statement of the Problem

It is not known how, or to what extent, the TI-Nspire impacts student understanding in CCA classrooms. The TI-Nspire is permitted on all New York State Mathematics Regents exams, the SAT, the ACT, and all IB exams. The SAT, ACT, and IB exams are not required for high school graduation in New York State, but the Regents exams are. The first mathematics Regents exam students take in New York State public schools is the CCA Regents Exam. For students to move onto higher math courses, they need to be fluent in the topics they have been taught. Conceptual understanding of topics supports this mathematical fluency. The TI-Nspire supports conceptual understanding of mathematics topics. Before school districts invest in TI-Nspire technology, it is necessary to understand what effect (if any) the technology impacts student achievement in CCA by measuring results on benchmark tests.

Research Questions and Hypotheses

The following research questions and hypotheses guide this study:

R1: What, if any, is the effect of using TI-Nspire technology in CCA courses as measured by overall student CCA benchmark test scores?

R2: Does use of TI-Nspire technology create higher scores on certain questions/topics (via item analysis and topic review analysis)? The specific topics are (1) interpreting functions, (2) building function, and (3) reasoning with equations and inequalities.

The research questions above sought to determine if the below hypotheses are verified as true or false.

H_1: There is not a relationship between students utilizing TI-Nspire technology in CCA courses and scores on the CCA benchmark tests.

H_0: There is not a relationship between the use of TI-Nspire technology and student performance on CCA questions/topics (as measured by the benchmark tests for the specified topics of (1) interpreting functions, (2) building function, and (3) reasoning with equations and inequalities.

The CCA sections that did not use TI-Nspire technology (independent variable) were defined as three sections of 9th grade CCA sections that used traditional instructional strategies (control group). The CCA courses that used TI-Nspire technology (dependent variable) were defined as three sections of CCA courses that utilized TI-Nspire technology as an alternative to traditional instructional strategies (experiment group).

To measure the student achievement, a series of tests were administered to both the control and experiment group. In total, two tests were used: (1) the pretest and (2) the posttest. These tests were developed by Glencoe Mc-Graw Hill from their Common Core Algebra 1 textbook. The use of a publisher versus teacher-generated exams is to ensure the validity and reliability of the data collected.

Research Methodology

This study examined student benchmark scores in CCA courses and an item-analysis of topics from the benchmark scores. All of this data is quantitative and naturally lent itself to a quantitative study. The research question stated, “What, if any, is the effect of using TI-Nspire technology in CCA courses as measured by overall student CCA benchmark test scores?” This research question specifically refers to the variables being analyzed: (1) the scores on the pretest and the posttest of students participating in the control group and (2) the scores on the pretest and the posttest of students participating in the experiment group.

This study is unique, as it will analyze the impact of the TI-Nspire on student achievement in CCA. The methodology of this study is based upon academic studies previously conducted. Hollar and Norwood (1999) compared groups of students who used graphing calculators (not TI-Nspire) in the Algebra classroom (not Common Core) versus students who did not. This research was quantitative by design and compared the results of a control with an experimental group. Khoju, Jaciw, and Miller (2005) performed a systematic review of graphing calculator effectiveness K-12. This study also utilized a quantitative research design in the same format of a using an experimental and control group. Again, while the methodology of the study is not unique, the subject of the research is.

Research Design

This study used data from six sections of Common Core Algebra classes (9th grade high school). Three of these sections used traditional graphing calculators while the other three sections used TI-Nspire technology. Students were placed into each section via a stratified sampling method. This technique was used because it has a higher statistical precision as compared with random sampling (Explorable.com, 2009). This is because there is less variability between each subgroup when dealing with the entire population. Explorable.com (2009) explained, “because this technique has high statistical precision, it also means that it requires a small sample size which can save a lot of time, money and effort of the researchers.” The stratified sampling method is discussed in further detail in the sampling section of this chapter.

It was not possible or practical to assign specific students into the control or experiment groups due to the course scheduling challenges within the high school environment. A quasi-experiment design was selected and used because it permits the analysis of the control group who used traditional methods as compared to the experiment group who used the TI-Nspire as an academic intervention, but did not permit random assignment of students participating in the study.

Students participating in the study completed a series of Algebra exams designed by textbook publisher Glencoe McGraw Hill. Benchmark testing occurred before and after the TI-Nspire intervention. Two data points were used in total: One pretest and one posttest. In addition to the benchmark testing, teachers were surveyed and observed to determine how frequently they used the TI-Nspire within the Algebra classroom. This was ongoing through the pretest and posttest period.

The student scores on the pretest and posttests were used to establish the effect (if any) of TI-Nspire technology (on the treatment versus the control groups). These tests were distributed to participants, then collected, then graded, and then recorded in an excel spreadsheet for analysis. Because the New York State Regents was aligned to the CCSS for the first time in June of 2014, prior year scores were not used for this study.

Population and Sample Selection

The site of this research study was conducted at Great Neck South High School. This school is located 15.7 miles East of Manhattan, New York. Demographic factors describing this suburban public high school are listed in tables 3.1, 3.2, and 3.3 below.

Table 3.1

Demographics of Great Neck South High School(New York State Education Department, 2013)

	2009-10		2010-11		2011-12	
	#	%	#	%	#	%
Eligible for Free Lunch	65	5	54	4	66	5
Reduced Price Lunch	41	3	45	3	50	4
Limited English Proficient	59	4	46	3	42	3
Racial/Ethnic Origin						

American Indian or Alaska Native	0	0	0	0	0	0
Black or African America	32	2	33	2	31	2
Hispanic or Latino	81	6	87	6	83	6
Asian or Native Hawaiian/Other	582	43	562	42	573	45
White	671	49	659	49	593	46
Multiracial	0	0	1	0	0	0

Table 3.2

Enrollment of Great Neck South High School(New York State Education Department, 2013)

	2009-10	2010-11	2011-12
Grade 7	0	0	0
Grade 8	0	0	0
Grade 9	316	325	297
Grade 10	346	350	327
Grade 11	346	350	316
Grade 12	358	347	340
Ungraded Secondary	0	0	1
Total K-12	1366	1342	1281

Table 3.3

Average class size of Great Neck South High School (New York State Education Department, 2013)

Grade 10	2009-10	2010-11	2011-12
English	25	24	23
Mathematics	19	18	22
Science	26	25	23
Social Studies	23	22	23

This study compared three sections that used the traditional approach to teaching CCA to three sections that used the TI-Nspire as alternative approach to teaching CCA. There were three teachers who participated in this study. To form these sections, a stratified sampling method was used where two stratums will be specified: (1) CCA students and (2) general education students (not special education or gifted). Random sampling was then used to select a sufficient number of subjects that satisfied both stratum requirements. Ninth grade students taking CCA participated in the study. Ninth grade students learned how to use the TI-Nspire as part of their coursework. These students were scheduled into six sections of CCA by Infinite Campus computer software, the district's course scheduling system. Each teacher taught one section of CCA utilizing traditional methods while using the TI-Nspire in the other section. The goal of this organization was to minimize teacher impact between the control and the experimental group. Hazari, North, and Moreland (2009) suggested this strategy "to control for treatment diffusion and expectancy threats" (p. 191). Steckroth (2008) supported this structure when he said, "to minimize the teacher effect, we preferred to work with two classes of students who were being taught at the same level by the same teacher, rather than confound the study by comparing students in different classes or taught by two different teachers" (p. 3). The six sections of students were assigned to the three teachers who participated in the study. The teachers were assigned which section would be the control group and which section would be the treatment group that utilized the TI-Nspire technology. All teachers of the research site have participated in a three-day training of the TI-Nspire as conducted by Texas Instruments. A total of 120-150 students were included in this study, 60-75 from the three treatment classes using the TI-Nspire and 60-75 from the three traditional CCA classes. The study will used 116 students due to students who opted out or have parents who opted them out.

Instrumentation

The Glencoe Algebra 1 (Carter, et al., 2014) textbook contains ancillary materials that included a pretest and a posttest that have been created by the McGraw-Hill Companies, Inc. For this study, these publisher-created materials were used as an instrument for data collection. This textbook was written for ninth graders who are enrolled in CCA courses. While it is not directly written to New York State Standards, the textbook is aligned to the National CCSS. The New York State Standards are based off of the National CCSS. The instruments only collected quantitative data from the two tests administered to the participants of the study.

The pretest

The Glencoe Algebra 1 textbook (Carter, et al., 2014) included a pre-assessment in the form of a diagnostic exam. The diagnostic is an initial assessment geared towards assessing students' initial CCA knowledge. This serves as an entry-level assessment prior to any CCA instruction and served as the pretest for this study. The pretest is included in Appendix A.

Posttest

The Glencoe Algebra 1 textbook (Carter, et al., 2014) included a posttest that served as a summative assessment for this study. The purpose of the posttest was to assess student success in learning the concepts taught with and without the TI-Nspire innovation. The posttest is included in Appendix B.

Validity and Reliability

This study used publisher created instruments to measure student achievement in CCA. The Glencoe Algebra 1 textbook (Carter, et al., 2014) included these tests as ancillary materials. The tests only collect data associated with the CCA coursework and nothing else. The McGraw-Hill Companies, Inc created the tests. Because these tests were written specifically for the CCSS, any school in any state that is participating in the CCSS could use them. Because the tests are nationally aligned, the internal and external reliability are supported

Data Collection Procedures

To determine which students would participate in this study, the researcher used the school district's school information system to determine how many sections of CCA were scheduled for the current school year. Those findings were filtered to eliminate sections that contained special education students. Then, the remaining findings were sorted to determine which teachers taught more than one CCA section. Three teachers and six sections of CCA that met the above criteria were selected. From each of the three teachers, one section was assigned to be a part of the control group using traditional methods while the other selection was assigned to be a part of the treatment group utilizing the TI-Nspire innovation. Because there are no honors sections of CCA in 9^{th} grade and no special education courses were included, equity of the demographics was created. Kirby (2006) discussed the importance of control for any confounding variables and that no group (control or treatment) have an advantage prior to the study. The pretest results served as a measure that both groups (control and treatment) were equitable prior to any data collection.

The two test instruments that were used did not appear any different from tests normally assigned within the CCA classroom. There were no special markings or other identification to associate the tests as a part of a research study. Sample participants were not aware that they were a part of a research study. The tests were given on regular testing days and use standard testing times (38 minutes).

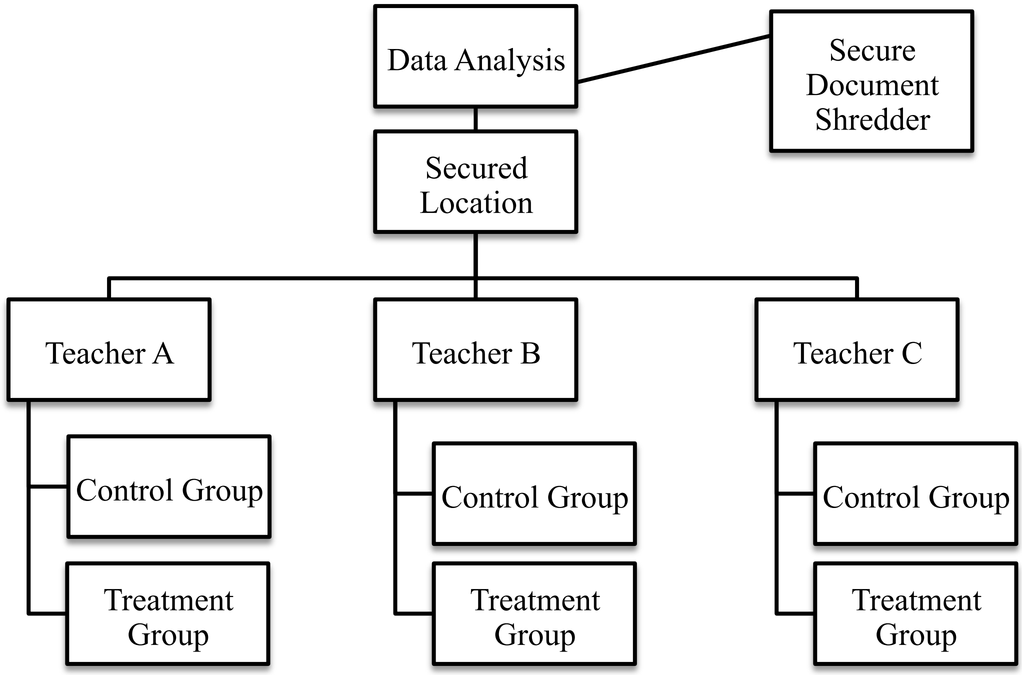

Figure 3.1. Organization of instrumentation and analysis

The test instruments were securely stored prior to being distributed to the teachers participating in the study. The location of the test instruments is illustrated in figure 3.1. Teachers employed by the school were trained in test administration and proctoring procedures by the district. This was required of all teachers, not just those who participated in the study. The training included how to maintain test security and accountability of test materials as well as encouraging a positive atmosphere for testing. The participating teachers were aware that the researcher will protect the confidentiality of students at all times and not publicize the test results. The researcher maintained test security of answer keys and item-specific scoring rubrics. Immediately after the administration of each exam, the instruments were sealed in a brown interoffice envelope by the proctor and personally collected by the researcher. At this time they were secured in a private locked office until they can be analyzed. Results from the test instruments were recorded in a password protected Microsoft excel spreadsheet. After the transfer of data was checked for accuracy, the original test documents were destroyed using a secure paper shredder.

Data Analysis Procedures

The data from the instruments were securely stored in a password protected Microsoft excel spreadsheet. This data was then transferred to Predictive Analytical Software (PASW- formerly known as SPSS) GradPack 17.0 for analysis. The analysis of the pretest was used to determine if the groups (control and treatment) were equitable and the posttest test analysis was used to determine any difference throughout the experiment process.

An ANOVA was used to detect if the means differ between the control and treatment groups. Using the pretest scores, an ANOVA was used to test the following hypothesis:

H_0: $\overline{x_1} = \overline{x_2} = \overline{x_3} = \overline{x_4} = \overline{x_5} = \overline{x_6}$

H_1: The means differ

Where $\overline{x_1}$, $\overline{x_2}$, and $\overline{x_3}$ represent the three treatment groups for Teacher A, Teacher B, and Teacher C respectfully. Conversely, $\overline{x_4}$, $\overline{x_5}$, and $\overline{x_6}$ represent the control groups for Teacher A, Teacher B, and Teacher C respectfully.

Data from the three control groups and three treatment groups were combined and used to test the following hypothesis:

H_0: $\overline{x_7} = \overline{x_8}$

H_1: $\overline{x_7} \neq \overline{x_8}$

Where $\overline{x_7}$ represents the mean score of all three treatment groups and $\overline{x_8}$ represents the mean score of all three control groups. An ANOVA and a t-test were used to determine if there was a difference between the combined posttest scores of the treatment groups $\overline{x_7}$ and the control groups $\overline{x_8}$.

A one-way MANOVA was used to analyze the posttest specifically for the item analysis and performance on the following topics: (1) interpreting functions, (2) building function, and (3) reasoning with equations and inequalities. These topics were selected because together they comprise 85% of the CCARE. The results from the questions of the posttest correlating to the specific topics were inserted into a password protected Excel spreadsheet and then transferred to Predictive Analytical Software (PASW- formerly known as SPSS) GradPack 17.0 for analysis. The one-way MANOVA tested for patterns and determine if patterns exist for the specific questions being analyzed.

Ethical Considerations

This study used students and teachers from a public school, therefore the use of student and teacher names were kept strictly confidential. Test data was stored in a secure location and not released with any students or staff. After analysis of the data, the tests were destroyed using a secure document paper shredder. The tests were administered on regular testing days. The tests did not appear any different from the regular algebra tests administered during the CCA coursework. There was no indication on the tests or by the participating teachers that the tests were used as a part of a research study. As noted earlier, teachers volunteered to participate in this research study. The CCA curriculum is rigorous and time consuming. This did not permit time for an in-depth study of any one particular topic. Participating teachers taught to the CCA curriculum and students in the experiment group did not lose any instructional time to complete the curriculum.

As an extra measure of ethical consideration, TI-Nspire calculators were placed in "test mode" during the two tests used in this study. The TI-Nspire then acts as though it is a standard graphing calculator, giving no advantage to the experimental group during the tests that were used for this study. This prevented the possibility of inequality between the experiment and control groups on these tests. The TI-Nspire was used as an instructional tool during this study. As noted in chapter two, the TI-Nspire served as an instrument of instruction for CCA and in real world situations.

Limitations

One limitation of this study was the generalization of the results. The students selected for this study was a small sample (school district) of a population (New York State) that is very diverse in ethnicity and limited in location. This small population may be very different from populations in other parts of the New York State as well as the entire United States of America. Other limitations may be the pedagogy that the individual teachers bring into their classrooms. No two teachers teach exactly alike. Although all three teachers were trained on how to use the TI-Nspire technology in their classrooms the individual teaching styles of the teachers may differ.

Communication between the students in the experiment and control groups cannot be controlled. There is a possibility that students from different sections could communicate with each other and share instructional materials and methods between the experiment and control groups. These limitations should not have a significant impact on the data to be collected.

Summary

This chapter began with a discussion of the research questions examined in this study. The key points of this chapter were: (1) introduction; (2) statement of the problem; (3) research questions and hypotheses; (4) research methodology; (5) research design; (6) population and sample selection; (7) instrumentation; (8) study parameters; (9) research methodology; (10)

instrumentation; (11) validity, (12) reliability; (13) data collection procedures; (14) data analysis procedures; (15) ethical considerations; (16) limitations, and (17) summary. The next chapter reports the results and the analysis of the data collected.

Chapter 4: Data Analysis and Results

Introduction

The data collected was analyzed to help determine if, or to what extent, the use of the TI-Nspire technology impacted student understanding in Common Core Algebra (CCA) classrooms. For this study, the CCA course was used because it is the first mathematics standardized exam (Regents) given to high school students. The Common Core Algebra Regents Exam (CCARE) is required for students to graduate high school in New York State. Graphing calculators are permitted on the CCARE, however, the TI-Nspire provides interactive tools, such as the multiple representation of a function, that traditional graphing calculators do not. The purpose of this study is to determine if students who use the TI-Nspire have a better understanding of CCA as compared to students who use traditional graphing calculators.

The purpose of this quantitative experimental research was to compare CCA courses that did not use TI-Nspire technology (independent variable) to CCA courses that used TI-Nspire technology (dependent variable). Teachers who participated in this study were selected at random. This was done to isolate teacher impact of the study. Three teachers were used in total. Each selected teacher taught two general education sections of CCA. Teachers were assigned one CCA class as a control group that used traditional graphing calculators, leaving the other class to use TI-Nspire technology as the treatment group. This provided a total of three control groups and three treatment groups.

The first administration of the CCARE was given in June of 2014. This recent administration did not permit this study to compare the results of this exam to prior administrations of the CCARE. Instead, this study used publisher-created benchmark tests that were aligned to the CCA course. In total, two tests were administered to both the control and treatment group (the pretest and the posttest). The pretest was administered as a baseline to determine if all six CCA courses participating in this research study were equal prior to the TI-Nspire intervention. The posttest was used to determine what effect, if any, the TI-Nspire technology had on CCA instruction.

As mentioned above, two data points will be used in total: One pretest and one posttest. The tests were from the Glencoe Algebra 1 (Carter, et al., 2014) textbook as part of the textbook ancillary materials created by the McGraw-Hill Companies, Inc.

The following research questions and hypotheses were used to guide this study:

R1: What, if any, is the effect of using TI-Nspire technology in CCA courses as measured by overall student CCA benchmark test scores?

R2: Does use of TI-Nspire technology create higher scores on certain questions/topics (via item analysis and topic review analysis)? The specific topics are: (1) interpreting functions, (2) building function, and (3) reasoning with equations and inequalities.

The research questions above were used to determine if the hypotheses below were verified as true or false.

H_1: There is no relationship between students utilizing TI-Nspire technology in CCA courses and scores on the CCA benchmark tests.

H_0: There is no relationship between the use of TI-Nspire technology and student performance on CCA questions/topics (as measured by the benchmark tests for the specified topics of (1) interpreting functions, (2) building function, and (3) reasoning with equations and inequalities.

This study used student benchmark scores from CCA courses and an item-analysis of the topics from the benchmark scores. All data collected was quantitative in nature and no qualitative data was collected. An ANOVA was used to analyze pretest scores to determine if all sections participating in this study were created equally. Using the pretest scores, an ANOVA was used to test the following hypothesis:

H_0: $\overline{x_1} = \overline{x_2} = \overline{x_3} = \overline{x_4} = \overline{x_5} = \overline{x_6}$

H_1: The means differ

Where $\overline{x_1}$, $\overline{x_2}$, and $\overline{x_3}$ represented the three treatment groups for Teacher A, Teacher B, and Teacher C respectfully. Conversely, $\overline{x_4}$, $\overline{x_5}$, and $\overline{x_6}$ represented the control groups for Teacher A, Teacher B, and Teacher C respectfully.

Data was also used to analyze the posttest scores to determine if there was a difference in control groups and treatment groups. Here, data from the three control groups and three treatment groups was combined and used to test the following hypothesis:

H_0: $\overline{x_7} = \overline{x_8}$

H_1: $\overline{x_7} \neq \overline{x_8}$

Where $\overline{x_7}$ represented the mean score of all three treatment groups and $\overline{x_8}$ represented the mean score of all three control groups. An ANOVA and a t-test were used to determine if there was a difference between the combined posttest scores of the treatment groups $\overline{x_7}$ and the control groups $\overline{x_8}$.

A one-way MANOVA was used to further analyze the posttest specifically for the item analysis and performance on the following topics: (1) interpreting functions, (2) building function, and (3) reasoning with equations and inequalities. The one-way MANOVA will test for patterns and determine if patterns exist for the specific questions being analyzed.

Data from the t-test, ANOVA, and MANOVA was done using Predictive Analytical Software (PASW- formerly known as SPSS) GradPack 17.0.

This chapter will summarize the collected data, how it was analyzed, and present the results. This chapter is divided into the following sections: (1) introduction; (2) descriptive data; (3) data analysis procedures; (4) results; and (5) summary.

Descriptive Data

As mentioned above, the purpose of this study is to determine if, or to what extent, the use of the TI-Nspire technology impacted student understanding in CCA classrooms. To conduct this experimental research study, it was first necessary to select three teachers who taught two sections of CCA. Then, a stratified sampling method was used to create each of the six sections. Two stratums were specified: (1) CCA students and (2) general education students (not special education or gifted). Finally, random sampling was used to select a sufficient number of subjects that satisfied both stratum requirements. The only students who meet both stratum requirements in the district are students in ninth grade. All students who participated in this study were between the ages of 13 and 15. As stated in chapter three, it was expected that 120-150 students would be included in this study. Students were permitted to opt-in or opt-out of this study. Due to this unpredictable variable, the total number of participants in this study was 116, different from what was mentioned in chapter three. Characteristics of the participants in this study are described in table 4.1 below.

Table 4.1

Characteristics of the participants of the study

	Control Group		Treatment Group		Total
	Males	Females	Males	Females	

Teacher A	9	12	7	8	36
Teacher B	7	9	8	10	34
Teacher C	10	13	10	13	46
Total	26	34	25	31	116

Teachers participating in this study were assigned one section of CCA to be the control group and the other section of CCA to be the treatment group. The purpose of the organization was to minimize the teacher impact between the control and experimental groups as suggested by Hazari, North, and Moreland (2009). This organizational strategy was also suggested by Steckroth (2008) when he said, "to minimize the teacher effect, we preferred to work with two classes of students who were being taught at the same level by the same teacher, rather than confound the study by comparing students in different classes or taught by two different teachers" (p. 3).

Results

Prior to addressing the research questions, it was necessary to identify if all sections participating in the study had students of equal mathematical ability. If one group had a higher mathematical ability, they may be expected to score higher on the CCARE. This study will refer to this starting knowledge as prior mathematical knowledge. To measure prior mathematical knowledge the pretest was used. Using the pretest scores, an ANOVA was used to test the following hypothesis:

H_0: $\overline{x_1} = \overline{x_2} = \overline{x_3} = \overline{x_4} = \overline{x_5} = \overline{x_6}$

H_1: The means differ

Where $\overline{x_1}$, $\overline{x_2}$, and $\overline{x_3}$ represented the three treatment groups for Teacher A, Teacher B, and Teacher C respectfully. Conversely, $\overline{x_4}$, $\overline{x_5}$, and $\overline{x_6}$ represented the control groups for Teacher A, Teacher B, and Teacher C respectfully. A one-way between groups analysis of variance (ANOVA) was used to compare the pretest scores from all six groups using the data in Table 4.2. The results from the ANOVA are displayed in Table 4.3

Table 4.2

Group Statistics from the pretest

	Teacher A		Teacher B		Teacher C	
Group	Control	Treatment	Control	Treatment	Control	Treatment
Sample Size	21	15	16	18	23	23
Mean	84.04	85.33	85.00	84.82	85.00	84.82
Standard Deviation	5.62	6.84	6.85	5.50	6.85	5.50

Table 4.3

Analysis of Variance on the pretest

	Sum of Squares	df	Mean Square	Fisher F-Value	Significance (p)
Between Groups:	18.423	5	3.685	0.096	0.993
Within Groups:	4188.718	109	38.429		
Total:	4207140	114			

ANOVA results showed that any differences between the mean pretest scores of the six classes were not statistically significant ($F_{(5, 109)} = .096$, $p = .0993$, $\alpha = 0.05$). Therefore, any difference of the mean score of the posttest is less likely caused by prior mathematical knowledge and more due to chance.

The ANOVA displayed above supported H_0 for the pretest scores. Next, an ANOVA and a t-test were used to compare posttest mean scores to answer the following research question:

R1: What, if any, is the effect of using TI-Nspire technology in CCA courses as measured by overall student CCA benchmark test scores?

To analyze the posttest data, the same hypotheses and confidence level were used as done with the pretest. The ANOVA for the posttest scores were used to determine if the means differ. When the means differ, post hoc tests can be used to identify which groups differ. In addition to the TI-Nspire technology, the time of day that the math class was offered, the teacher-student relationships, the individual teaching style, the size of the class, and the effect of the treatment can cause the differences identified above. A one-way between groups analysis of variance (ANOVA) was used to compare the posttest scores from all six groups using the data in Table 4.4. The results from the ANOVA are displayed in Table 4.5.

Table 4.4
Group Statistics from the posttest

	Teacher A		Teacher B		Teacher C	
Group	Control	Treatment	Control	Treatment	Control	Treatment
Sample Size	21	15	16	18	23	23
Mean	75.87	85.88	75.00	83.70	79.71	81.75

Standard Deviation	8.62	8.62	8.34	11.25	10.15	9.23

Table 4.5

Analysis of Variance on the posttest

	Sum of Squares	df	Mean Square	Fisher F-Value	Significance (p)
Between Groups:	1650.612	5	330.112	3.695	0.004
Within Groups:	9737.185	109	89.332		
Total:	11387.797	114			

There was a statistically significant difference at the p <.05 level, so we reject the null hypothesis that the means of the posttest scores for the four samples are equivalent. More specifically, the means for the six groups are statistically different from each other. Because of the statistically different means, a Bonferroni post hoc test was performed to identify the specific groups where the means differ. The results from the Bonferroni post hoc test are displayed in Table 4.6. There is a statistically significant difference (p = 0.049) in mean scores between control group B and treatment group A.

Table 4.6

Analysis of Variance post hoc test

Dependent Variable: Score
Bonferroni

					95% Confidence Interval	
(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Control A	Control B	.87302	3.17264	1.000	-8.6470	10.3930
	Control C	-3.83713	2.88564	1.000	-12.4959	4.8217

	Treatment A	-9.46032	3.23210	.062	-19.1587	.2381
	Treatment B	-7.83069	3.07097	.182	-17.0456	1.3842
	Treatment C	-4.85162	2.88564	1.000	-13.5104	3.8072
Control B	Control A	-.87302	3.17264	1.000	-10.3930	8.6470
	Control C	-4.71014	3.11241	1.000	-14.0494	4.6291
	Treatment A	-10.33333*	3.43609	.049	-20.6439	-.0228
	Treatment B	-8.70370	3.28498	.139	-18.5608	1.1534
	Treatment C	-5.72464	3.11241	1.000	-15.0639	3.6146
Control C	Control A	3.83713	2.88564	1.000	-4.8217	12.4959
	Control B	4.71014	3.11241	1.000	-4.6291	14.0494
	Treatment A	-5.62319	3.17301	1.000	-15.1443	3.8979
	Treatment B	-3.99356	3.00871	1.000	-13.0217	5.0346
	Treatment C	-1.01449	2.81929	1.000	-9.4742	7.4452
Treatment A	Control A	9.46032	3.23210	.062	-.2381	19.1587
	Control B	10.33333*	3.43609	.049	.0228	20.6439
	Control C	5.62319	3.17301	1.000	-3.8979	15.1443
	Treatment B	1.62963	3.34244	1.000	-8.3999	11.6592
	Treatment C	4.60870	3.17301	1.000	-4.9124	14.1298
Treatment B	Control A	7.83069	3.07097	.182	-1.3842	17.0456
	Control B	8.70370	3.28498	.139	-1.1534	18.5608
	Control C	3.99356	3.00871	1.000	-5.0346	13.0217
	Treatment A	-1.62963	3.34244	1.000	-11.6592	8.3999
	Treatment C	2.97907	3.00871	1.000	-6.0490	12.0072
Treatment C	Control A	4.85162	2.88564	1.000	-3.8072	13.5104
	Control B	5.72464	3.11241	1.000	-3.6146	15.0639
	Control C	1.01449	2.81929	1.000	-7.4452	9.4742
	Treatment A	-4.60870	3.17301	1.000	-14.1298	4.9124
	Treatment B	-2.97907	3.00871	1.000	-12.0072	6.0490

**. The mean difference is significant at the 0.05 level.*

Next, data from the three control groups and three treatment groups was combined and used to test the following hypothesis:

H_0: $\overline{x_7} = \overline{x_8}$

H_1: $\overline{x_7} \neq \overline{x_8}$

Where $\overline{x_7}$ represented the mean score of all three treatment groups and $\overline{x_8}$ represented the mean score of all three control groups. A t-test was used to determine if there was a difference between the combined posttest scores of the treatment groups $\overline{x_7}$ and the control groups $\overline{x_8}$.

The t-test is a statistic that examines the difference between two mutually exclusive groups of one variable. A t-test revealed a statistically reliable difference between the combined posttest scores of the treatment groups and the control groups $\overline{x_8}$, $t(114) = -3.69$, $p = .002$, $\alpha = .05$. The output from the t-test is displayed below in Table 4.7

Table 4.7

T-test for equality of means

		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
Score	Equal variances assumed	.725	.396	-3.69	114	.002	-5.80556	1.78515	-1.981	1.981
	Equal variances not assumed			-3.24	111.696	.002	-5.80556	1.78976	-1.981	1.981

Using the t-test, (t = -3.69) falls outside the confidence interval rejecting the null hypothesis. This showed that there was a statistically significant difference between the mean score of the treatment group and that of the control group.

The next phases of the data analysis were to answer the following research question:

R2: Does use of TI-Nspire technology create higher scores on certain questions/topics (via item analysis and topic review analysis)? The specific topics are: (1) interpreting functions, (2) building functions, and (3) reasoning with equations and inequalities.

To address this research question a one-way multivariate analysis of variance (one-way MANOVA) was used. The purpose was to determine whether any differences between control and treatment group performance on posttest questions pertaining to: (1) interpreting functions, (2) building functions, and (3) reasoning with equations and inequalities. These topics were selected because they are core topics aligned with the CCA curriculum (Carter, et al., 2014). The posttest addressed interpreting functions in questions 1-10. Questions 25-28 addressed building functions while questions 11-20 addressed reasoning with equations and inequalities. To include this data in the one-way MANOVA, a sub-score for each participant was created in each of the three categories. This sub-score reported scores from each category out of 100.

Using Predictive Analytical Software (PASW- formerly known as SPSS) GradPack 17.0, the following fixed factors or independent variables where set up: (1) control and treatment groups, and (2) teacher group A, B, and C. The following dependent variables were set up: (1) interpreting functions, (2) building functions, and (3) reasoning with equations and inequalities. Table 4.8 below displays the between-subjects factors inputted into PASW.

Table 4.8

Posttest MANOVA between-subjects factors

		Value Label	*N*
Group	1.00	Control	60
	2.00	Treatment	56
Section	1.00	Teacher A	36
	2.00	Teacher B	34
	3.00	Teacher C	46

Table 4.9 below displays the descriptive statistics table generated by PASW. The table provided the mean and standard deviation for the three different dependent variables, which are split by the independent variables. Also, the descriptive statistics table provided total rows, where means and standard deviations are provided for each group.

Table 4.9

Posttest MANOVA descriptive statistics

	Group	Section	Mean	Std. Deviation	*N*
Interpreting Functions	Control	Teacher A	77.1429	15.53797	21
		Teacher B	78.1250	13.27592	16
		Teacher C	83.4783	13.00654	23
		Total	79.8333	14.08108	60
	Treatment	Teacher A	85.3333	12.45946	15
		Teacher B	88.8889	10.78610	18
		Teacher C	91.7391	8.86883	23
		Total	89.1071	10.66460	56
	Total	Teacher A	80.5556	14.72499	36
		Teacher B	83.8235	13.03020	34
		Teacher C	87.6087	11.77281	46
		Total	84.3103	13.33346	116
Building Functions	Control	Teacher A	71.4286	11.95229	21
		Teacher B	68.7500	13.60147	16
		Teacher C	72.6087	10.53884	23
		Total	71.1667	11.80228	60

	Treatment	Teacher A	84.0000	13.52247	15
		Teacher B	82.7778	11.27494	18
		Teacher C	80.0000	14.45998	23
		Total	81.9643	13.13145	56
	Total	Teacher A	76.6667	13.93864	36
		Teacher B	76.1765	14.14529	34
		Teacher C	76.3043	13.05692	46
		Total	76.3793	13.53877	116
Reasoning Inequalities	Control	Teacher A	78.5714	14.33029	21
		Teacher B	76.5625	24.94786	16
		Teacher C	78.2609	18.92621	23
		Total	77.9167	19.02923	60
	Treatment	Teacher A	93.3333	14.84042	15
		Teacher B	84.7222	24.46319	18
		Teacher C	80.4348	29.15137	23
		Total	85.2679	24.66908	56
	Total	Teacher A	84.7222	16.12205	36
		Teacher B	80.8824	24.66351	34
		Teacher C	79.3478	24.32668	46
		Total	81.4655	22.14593	116

Table 4.10 below displays the multivariate tests generated by PASW. This table is where the results of the one-way MANOVA were found. The second effect “group” and the *Wilks’ Lambda* were used to determine whether the one-way MANOVA was statistically significant. Table 4.10 showed a significance level of $p < .05$. By this data, we can conclude that there was a statistically significant difference in performance of: (1) interpreting functions, (2) building functions, and (3) reasoning with equations and inequalities based on a participant’s control versus treatment group, ($F_{(3, 108)} = 11.48, p < .05$); (*Wilk's* $\Lambda = 0.758$), (*partial* $\eta 2 = .24$) (Laerd Statistics, n.d.).

Table 4.10

Posttest MANOVA multivariate tests

Effect		Value	*F*	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.988	2912.258[a]	3.000	108.000	.000	.988
	Wilks' Lambda	.012	2912.258[a]	3.000	108.000	.000	.988
	Hotelling's Trace	80.896	2912.258[a]	3.000	108.000	.000	.988
	Roy's Largest Root	80.896	2912.258[a]	3.000	108.000	.000	.988
Group	Pillai's Trace	.242	11.477[a]	3.000	108.000	.000	.242
	Wilks' Lambda	.758	11.477[a]	3.000	108.000	.000	.242
	Hotelling's Trace	.319	11.477[a]	3.000	108.000	.000	.242
	Roy's Largest Root	.319	11.477[a]	3.000	108.000	.000	.242
Section	Pillai's Trace	.071	1.336	6.000	218.000	.242	.035
	Wilks' Lambda	.929	1.344[a]	6.000	216.000	.239	.036
	Hotelling's Trace	.076	1.352	6.000	214.000	.236	.037
	Roy's Largest Root	.072	2.612[c]	3.000	109.000	.055	.067
Group * Section	Pillai's Trace	.027	.494	6.000	218.000	.813	.013
	Wilks' Lambda	.973	.490[a]	6.000	216.000	.815	.013
	Hotelling's Trace	.027	.486	6.000	214.000	.818	.013
	Roy's Largest Root	.021	.751[c]	3.000	109.000	.524	.020

a. Exact statistic

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

*d. Design: Intercept + Group + Section + Group * Section*

Because of the statistically different subtest scores, a Bonferroni post hoc test was performed to identify the specific groups where the subtest scores differ. The results from the Bonferroni post hoc test are displayed in Table 4.11 below.

Table 4.11

MANOVA post hoc test

Bonferroni

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound

Interpreting_ Functions	Control A	Control B	-.9821	4.13450	1.000	-13.3884	11.4241
		Control C	-6.3354	3.76049	1.000	-17.6193	4.9485
		Treatment A	-8.1905	4.21199	.816	-20.8292	4.4483
		Treatment B	-11.7460	4.00201	.061	-23.7547	.2626
		Treatment C	-14.5963*	3.76049	.003	-25.8802	-3.3123
	Control B	Control A	.9821	4.13450	1.000	-11.4241	13.3884
		Control C	-5.3533	4.05602	1.000	-17.5240	6.8175
		Treatment A	-7.2083	4.47782	1.000	-20.6447	6.2281
		Treatment B	-10.7639	4.28090	.201	-23.6094	2.0816
		Treatment C	-13.6141*	4.05602	.016	-25.7849	-1.4434
	Control C	Control A	6.3354	3.76049	1.000	-4.9485	17.6193
		Control B	5.3533	4.05602	1.000	-6.8175	17.5240
		Treatment A	-1.8551	4.13499	1.000	-14.2627	10.5526
		Treatment B	-5.4106	3.92088	1.000	-17.1758	6.3546
		Treatment C	-8.2609	3.67403	.398	-19.2854	2.7636
	Treatment A	Control A	8.1905	4.21199	.816	-4.4483	20.8292
		Control B	7.2083	4.47782	1.000	-6.2281	20.6447
		Control C	1.8551	4.13499	1.000	-10.5526	14.2627
		Treatment B	-3.5556	4.35579	1.000	-16.6258	9.5147
		Treatment C	-6.4058	4.13499	1.000	-18.8135	6.0019
	Treatment B	Control A	11.7460	4.00201	.061	-.2626	23.7547
		Control B	10.7639	4.28090	.201	-2.0816	23.6094
		Control C	5.4106	3.92088	1.000	-6.3546	17.1758
		Treatment A	3.5556	4.35579	1.000	-9.5147	16.6258
		Treatment C	-2.8502	3.92088	1.000	-14.6155	8.9150
	Treatment C	Control A	14.5963*	3.76049	.003	3.3123	25.8802
		Control B	13.6141*	4.05602	.016	1.4434	25.7849
		Control C	8.2609	3.67403	.398	-2.7636	19.2854
		Treatment A	6.4058	4.13499	1.000	-6.0019	18.8135
		Treatment B	2.8502	3.92088	1.000	-8.9150	14.6155
Building Functions	Control A	Control B	2.6786	4.17320	1.000	-9.8438	15.2009
		Control C	-1.1801	3.79569	1.000	-12.5697	10.2094
		Treatment A	-12.5714	4.25141	.057	-25.3285	.1856
		Treatment B	-11.3492	4.03947	.088	-23.4703	.7718
		Treatment C	-8.5714	3.79569	.389	-19.9610	2.8181
	Control B	Control A	-2.6786	4.17320	1.000	-15.2009	9.8438
		Control C	-3.8587	4.09398	1.000	-16.1433	8.4259
		Treatment A	-15.2500*	4.51973	.015	-28.8122	-1.6878
		Treatment B	-14.0278*	4.32096	.023	-26.9935	-1.0620

		Treatment C	-11.2500	4.09398	.105	-23.5346	1.0346
	Control C	Control A	1.1801	3.79569	1.000	-10.2094	12.5697
		Control B	3.8587	4.09398	1.000	-8.4259	16.1433
		Treatment A	-11.3913	4.17369	.111	-23.9151	1.1325
		Treatment B	-10.1691	3.95758	.173	-22.0444	1.7062
		Treatment C	-7.3913	3.70842	.731	-18.5190	3.7364
	Treatment A	Control A	12.5714	4.25141	.057	-.1856	25.3285
		Control B	15.2500*	4.51973	.015	1.6878	28.8122
		Control C	11.3913	4.17369	.111	-1.1325	23.9151
		Treatment B	1.2222	4.39656	1.000	-11.9703	14.4148
		Treatment C	4.0000	4.17369	1.000	-8.5238	16.5238
	Treatment B	Control A	11.3492	4.03947	.088	-.7718	23.4703
		Control B	14.0278*	4.32096	.023	1.0620	26.9935
		Control C	10.1691	3.95758	.173	-1.7062	22.0444
		Treatment A	-1.2222	4.39656	1.000	-14.4148	11.9703
		Treatment C	2.7778	3.95758	1.000	-9.0975	14.6531
	Treatment C	Control A	8.5714	3.79569	.389	-2.8181	19.9610
		Control B	11.2500	4.09398	.105	-1.0346	23.5346
		Control C	7.3913	3.70842	.731	-3.7364	18.5190
		Treatment A	-4.0000	4.17369	1.000	-16.5238	8.5238
		Treatment B	-2.7778	3.95758	1.000	-14.6531	9.0975
Reasoning Inequalities	Control A	Control B	2.0089	7.30300	1.000	-19.9049	23.9227
		Control C	.3106	6.64236	1.000	-19.6209	20.2420
		Treatment A	-14.7619	7.43988	.746	-37.0864	7.5626
		Treatment B	-6.1508	7.06897	1.000	-27.3624	15.0608
		Treatment C	-1.8634	6.64236	1.000	-21.7948	18.0681
	Control B	Control A	-2.0089	7.30300	1.000	-23.9227	19.9049
		Control C	-1.6984	7.16438	1.000	-23.1962	19.7995
		Treatment A	-16.7708	7.90943	.543	-40.5043	6.9626
		Treatment B	-8.1597	7.56159	1.000	-30.8495	14.5300
		Treatment C	-3.8723	7.16438	1.000	-25.3701	17.6255
	Control C	Control A	-.3106	6.64236	1.000	-20.2420	19.6209
		Control B	1.6984	7.16438	1.000	-19.7995	23.1962
		Treatment A	-15.0725	7.30386	.621	-36.9888	6.8439
		Treatment B	-6.4614	6.92567	1.000	-27.2429	14.3202
		Treatment C	-2.1739	6.48965	1.000	-21.6471	17.2993
	Treatment A	Control A	14.7619	7.43988	.746	-7.5626	37.0864
		Control B	16.7708	7.90943	.543	-6.9626	40.5043
		Control C	15.0725	7.30386	.621	-6.8439	36.9888

	Treatment B	8.6111	7.69387	1.000	-14.4756	31.6978
	Treatment C	12.8986	7.30386	1.000	-9.0178	34.8149
Treatment B	Control A	6.1508	7.06897	1.000	-15.0608	27.3624
	Control B	8.1597	7.56159	1.000	-14.5300	30.8495
	Control C	6.4614	6.92567	1.000	-14.3202	27.2429
	Treatment A	-8.6111	7.69387	1.000	-31.6978	14.4756
	Treatment C	4.2874	6.92567	1.000	-16.4941	25.0690
Treatment C	Control A	1.8634	6.64236	1.000	-18.0681	21.7948
	Control B	3.8723	7.16438	1.000	-17.6255	25.3701
	Control C	2.1739	6.48965	1.000	-17.2993	21.6471
	Treatment A	-12.8986	7.30386	1.000	-34.8149	9.0178
	Treatment B	-4.2874	6.92567	1.000	-25.0690	16.4941

Based on observed means.
The error term is Mean Square(Error) = 484.328.
**. The mean difference is significant at the*

First, the subscores of interpreting functions were analyzed. When comparing control group A with treatment group C, $p = 0.003$ indicating a statistically significant difference between the two groups. When comparing control group B with treatment group C, $p = 0.016$ indicating a statistically significant difference between the two groups.

Second, the subscores of building functions were analyzed. When comparing control group B with treatment group A, $p = 0.015$ indicating a statistically significant difference between the two groups. When comparing control group B with treatment group B, $p = 0.023$ indicating a statistically significant difference between the two groups.

There were no statistically significant differences found when analyzing the groups in regards to the subscores for reasoning with inequalities.

Summary

This chapter began with a discussion of the purpose and research questions examined in this study. The key points of this chapter were: (1) descriptive data, (2) data analysis procedures, and (3) results. First, the research question "What, if any, is the effect of using TI-Nspire technology in CCA courses as measured by overall student CCA benchmark test scores?" was addressed. It was determined that the means of the pretest scores were statistically equivalent across the control and treatment groups. It was then determined that means of the posttest scores were statistically different across the control and treatment groups. Because of the statistically different means, a Bonferroni post hoc test was performed to identify the specific groups where the means differ. The test revealed that there is a statistically significant difference between control group B and treatment group A when comparing mean scores. In addition to the ANOVA, a t-test was used to analyze the posttest scores. The t-test also showed that there was a statistically significant difference between the mean score of the combined treatment groups and that of the control groups.

Next, the research question "Does use of TI-Nspire technology create higher scores on certain questions/topics (via item analysis and topic review analysis)? The specific topics are: (1) interpreting functions, (2) building functions, and (3) reasoning with equations and inequalities." was addressed. A one-way MANOVA revealed that there was a statistically significant difference in performance of: (1) interpreting functions, (2) building functions, and (3) reasoning with equations and inequalities based on a participant's control versus treatment group. Because of the statistically different subtest scores, a Bonferroni post hoc test was performed to identify the specific groups where the subtest scores differ. The test revealed that there is a statistically significant difference between the control and treatment groups for interpreting functions and building functions. The test also revealed that there was no statistically significant difference between the control and treatment groups subscores for reasoning with inequalities.

The next chapter is a comprehensive summary of the entire study. It explains how the study intended to contribute to the body of knowledge on graphing calculator use in CCA. It discusses the conclusions, implications, and recommendations of the study.

Chapter 5: Summary, Conclusions, and Recommendations

Introduction

This chapter is a comprehensive summary of the entire study. It explains how the study intended to contribute to the body of knowledge on graphing calculator use in CCA. It discusses the conclusions, implications, and recommendations of the study. This chapter is divided into the following sections: (1) introduction, (2) summary of the study, (3) summary of findings and conclusion, (4) implications, and (5) recommendations.

The purpose of this study was to determine how, or to what extent, the TI-Nspire impacts student understanding in CCA classrooms. The TI-Nspire is permitted on all New York State Mathematics Regents exams, the SAT, the ACT, and all IB exams. The SAT, ACT, and IB exams are not required for high school graduation in New York State, but the Regents exams are. The first mathematics Regents exam students take in New York State public schools is the CCA Regents Exam. For students to move onto higher math courses, they need to be fluent in the topics they have been taught. Conceptual understanding of topics supports this mathematical fluency. The TI-Nspire supports conceptual understanding of mathematics topics. Before school districts invest in TI-Nspire technology, it is necessary to understand what effect (if any) the technology impacts instruction and results in CCA by way of valid research.

As mentioned in chapter 1, studies have been conducted analyzing the use of a graphing calculator to other courses. One example is a quantitative study by Hollar and Norwood (1999) analyzing the effectiveness of the graphing calculator. Another example is a quantitative study by Doerr and Zangor (2000) that discussed the role of the graphing calculator in the Calculus classroom. Few studies exist linking their effectiveness towards CCA courses. Therefore a study to determine if the TI-Nspire has an effect on CCA courses was both original and necessary.

The purpose of this study was to determine if, or to what extent, the use of the TI-Nspire technology impacted student understanding in CCA classrooms. For this study, the CCA course was used because it is the first mathematics standardized exam (Regents) given to high school students. The CCARE is required for students to graduate high school in New York State. Graphing calculators are permitted on the CCARE, however, the TI-Nspire provides interactive tools, such as the multiple representation of a function, that traditional graphing calculators do not. The purpose of this study is to determine if students who use the TI-Nspire have a better understanding of CCA as compared to students who use traditional graphing calculators.

Summary of the Study

The purpose of this quantitative experimental research was to compare CCA courses that did not use TI-Nspire technology (independent variable) to CCA courses that used TI-Nspire technology (dependent variable). The first administration of the CCARE was given in June of 2014. This recent administration did not permit this study to compare the results of this exam to prior administrations of the CCARE. Instead, this study used publisher-created benchmark tests that were aligned to the CCA course. In total, two tests were administered to both the control and treatment group (the pretest and the posttest). The pretest was administered as a baseline to determine if all six CCA courses participating in this research study were equal prior to the TI-Nspire intervention. The posttest was used to determine what effect, if any, the TI-Nspire technology had on CCA instruction.

As mentioned above, two data points will be used in total: One pretest and one posttest. The tests were from the Glencoe Algebra 1 (Carter, et al., 2014) textbook as a part of the ancillary materials created by the McGraw-Hill Companies, Inc.

The following research questions and hypotheses were used to guide this study:

R1: What, if any, is the effect of using TI-Nspire technology in CCA courses as measured by overall student CCA benchmark test scores?

R2: Does use of TI-Nspire technology create higher scores on certain questions/topics (via item analysis and topic review analysis)? The specific topics are: (1) interpreting functions, (2) building function, and (3) reasoning with equations and inequalities.

The research questions above were used to determine if the hypotheses below were verified as true or false.

H_1: There is not a relationship between students utilizing TI-Nspire technology in CCA courses and scores on the CCA benchmark tests.

H_0: There is not a relationship between the use of TI-Nspire technology and student performance on CCA questions/topics (as measured by the benchmark tests for the specified topics of (1) interpreting functions, (2) building function, and (3) reasoning with equations and inequalities.

To establish if all control and treatment groups were created equally, an ANOVA was conducted on the pretest scores to determine if the means of the pretest scores were statistically equivalent. The posttest was used to answer the research questions above. First, an ANOVA was conducted, this time using posttest scores to determine if the means were statistically equivalent across the control and treatment groups. Next, scores from the control groups were combined into one mean while scores from the treatment groups were combined into one mean. This reduced the data from six means to two. Those two means were analyzed using a t-test to determine if the means were significantly different between the control and treatment groups. Finally, a MANOVA was used to test for patters and determine if patterns exist for the specific questions being analyzed by the second research question.

Summary of Findings and Conclusion

First an analysis of variance (ANOVA) was used to compare the means of the pretest scores. The purpose was to insure that all groups were created equally. This data was analyzed using a 95% confidence level, since ($p > 0.05$), that determined there was no significant difference of the mean scores of the pretest in any of the six sections participating in the study. Therefore, any difference of the mean score of the posttest is less likely caused by prior mathematical knowledge before the treatment was applied.

To address the first research question, “What, if any, is the effect of using TI-Nspire technology in CCA courses as measured by overall student CCA benchmark test scores?” a separate analysis of variance (ANOVA) was used to compare the means of the posttest scores. Unlike the pretest, ($p < .05$) rejects the null hypothesis showing that the means of the posttest scores for the four samples are not statistically equivalent. More specifically, the means for the three treatment groups are statistically different as compared to the means of the three control groups. Since the null hypothesis was rejected, we can say there is a relationship between students utilizing TI-Nspire technology in CCA courses and scores on the CCA benchmark tests.

Because of the statistically different means, a Bonferroni post hoc test was performed to identify the specific groups where the means differ.

The significance (p) of Table was analyzed to determine if any values where $p > 0.05$ existed. This would show a statistically significant difference between the groups (Laerd Statistics, n.d.). When comparing control group B with treatment group A, $p = 0.049$. This shows that there is a statistically significant difference between control group B and treatment group A when comparing mean scores.

To further support this claim, a t-test was used to compare combined means of the control and treatment groups. Using a 95% confidence level with 114 degrees of freedom, the confidence interval falls between -1.981 and 1.981. If the t-score falls on either side of this region, we can reject the null hypothesis. Using a t-test, ($t = -3.69$) falls outside the confidence interval rejecting the null hypothesis. This showed that there was a statistically significant difference between the mean score of the treatment group and that of the control group. Equivalently, this t-score corresponded to a p-value of (0.000345). The *p-value / 2* is equal to 0.0001725 which is less that the alpha value divided by 2 or $\alpha/2 = 0.025$. This difference could be attributed to the TI-Nspire supporting the idea that the TI-Nspire technology improves student understand in CCA.

The data revealed that not all of the control groups were statistically different than the treatment groups. There could be several reasons for this. While conducting informal teacher interviews and observations of the study, teachers reported that some students did not prefer to use the calculator as frequently as other students. This may have decreased the gap between some of the control and treatment groups with their respective posttest mean scores.

To address the second research question, “Does use of TI-Nspire technology create higher scores on certain questions/topics (via item analysis and topic review analysis)? The specific topics are: (1) interpreting functions, (2) building function, and (3) reasoning with equations and inequalities." a one-way multivariate analysis of variance (one-way MANOVA) was used to determine if any differences between control and treatment group performance existed. From the collected data, we can conclude that there was a statistically significant difference in performance of: (1) interpreting functions, (2) building functions, and (3) reasoning with equations and inequalities based on a participant's control versus treatment group, ($F(3, 108) = 11.48$), ($p < .0005$); (*Wilk's* $\Lambda = 0.758$), (*partial* $\eta 2 = .24$) (Laerd Statistics, n.d.).

Because of the statistically different subtest scores, a Bonferroni post hoc test was performed to identify the specific groups where the subtest scores differ.

The significance level (p) of Table was analyzed to determine if any values where $p > 0.05$ existed. This would show a statistically significant difference between the groups(Laerd Statistics, n.d.).

First, the subscores of interpreting functions were analyzed. When comparing control group A with treatment group C, $p = 0.003$. When comparing control group B with treatment group C, $p = 0.016$. This shows that there is a statistically significant difference between control group A and treatment group C when comparing subscores for interpreting functions. The same is true when comparing control group B and treatment group C.

Second, the subscores of building functions were analyzed. When comparing control group B with treatment group A, $p = 0.015$. When comparing control group B with treatment group B, $p = 0.023$. This shows that there is a statistically significant difference between control group B and treatment group A when comparing subscores for interpreting functions. The same is true when comparing control group B and treatment group B.

There were no statistically significant differences found when analyzing the groups in regards to the subscores for reasoning with inequalities. There could be several reasons for this.

While conducting informal teacher interviews and observations of the study, teachers reported they felt stronger teaching inequalities using traditional methods as opposed to with the TI-Nspire technology. This intrinsic preference could have unintentionally been transferred to the students in both the control and treatment groups, creating similarities in posttest performance on the topic of inequalities. This could be one reason there was no statistically significant difference found when analyzing the groups in regards to the subscores for reasoning with inequalities.

Implications

Theoretical Implications.

Hollar and Norwood (1999) focused on the use of graphing calculators and how it related to performance in intermediate algebra. That study used TI-82 graphing calculators, that is very different from the TI-Nspire technology. That study also examined the intermediate algebra curriculum designed for college students, while this research examined CCA that is aligned to the high school curriculum. The results of that study support the use of graphing calculators and their relationship to academic performance in intermediate algebra. Theories of technology implementation including using the technology as a mediating tool were discussed in Chapter 2. The didactical triangle (Persson, 2011) explained how technological tools, such as a TI-Nspire, could act as a facilitating tool between teachers, students, and learning outcome. Brousseau (1997) explained the theory of mathematical learning-teaching process using calculators as tools for calculating, teaching, and learning. This theory is supports the statistically different posttest means of groups who used the TI-Nspire technology. The TI-Nspire technology was not just used as a posttest calculator, but as a mediation tool between teacher and student as the CCA curriculum was taught.

Practical Implications.

Practical implications delineate applications of new insights derived from the dissertation to solve real and significant problems. The practical implications apply to the use of the TI-Nspire in CCA classrooms for schools who are participating in the CCSS. School districts and secondary school mathematics departments need to use research as they select which technologies to purchase for their schools. However, it is just as important to provide both students and educators with the professional learning to accompany the technology. This prevents the technology from being used as a gimmick, or using technology just for the sake of using something technological. The researcher details the need for not only matching the technology to the curriculum, but to the natural pedagogy and teaching style of the individual teacher who will use the technology.

Future Implications.

The research findings led to implications for educational practice. The statistically different means of the posttest scores between the control and treatment groups showed the importance of the TI-Nspire in the CCA classroom. Schools who incorporate the CCSS need to examine the use of TI-Nspire technology and see if it will benefit teachers and students. The results of this research study can be used to help guide school leaders to best equip their teachers and students for mathematical success.

Most schools will purchase technology innovations, such as the TI-Nspire, for their teachers and not spend time using it as a teaching tool. The presence of technology does not yield results unless both teachers and students are shown to use it as a learning device. While this study focused on TI-Nspire technology, the same theories and philosophies could be used for other technological innovations, even those that do not yet exist. By examining how technology is used, and for what purpose, school leaders can better understand how it can help (or hinder) the academic success of a students they serve.

Recommendations

Recommendations for Future Research.

Three major recommendations are made here for future research in the area of TI-Nspire use in the CCA classroom. The purpose of these recommendations is to provide a deeper understanding of the relationships between the variables studied and how they contributed to the results of this study. They are also meant to provide additional resources to school leaders who are responsible for a CCSS mathematics program. First, the researcher recommends expanding the research to include areas of CCA beyond the specified topics of (1) interpreting functions, (2) building function, and (3) reasoning with equations and inequalities. Functions and capabilities of the TI-Nspire could reveal specific strengths in other CCA topics. The second recommendation of the researcher is to incorporate the use of the TI-Navigator system with the TI-Nspire interactive graphing calculator. The TI-Navigator system enables calculators to connect wirelessly to a main teacher computer. This provides the teacher with more interactive ways teachers can conceptually demonstrate mathematical concepts. The third recommendation of the researcher is to expand this study into other CCSS mathematics courses in New York State. In June of 2015, the first Common Core Geometry exam will be given, followed by the first Algebra 2 Common Core Exam in June of 2016. As the curriculum shifts from topics of rote memorization to ideas that require conceptual understanding, it is important for school leaders to understand how the TI-Nspire technology can help students learn the new curricula.

Recommendations for Practice.

The participants of this study came from one high school that draws from a certain geographic area. If this study were to be conducted again, the researcher would recommend expanding the geographic area to include more school districts. This would provide a wider range of demographics that could be analyzed and compared using subgroups. School leaders could use this data to relate to their school's demographics to determine if the TI-Nspire would benefit their students.

The participants of this study provided data that was collected by a pretest and a posttest. This was 100% quantitative data and was based purely on mathematics tests. If this study were to be conducted again, the researcher would recommend using a mixed methods approach. While the quantitative data is accurate and valid, it does not tell the entire story. A qualitative survey could be used to collect the thoughts and perceptions of the TI-Nspire technology from both teachers and students. This would provide school leaders and teachers who are considering using TI-Nspire technology more details of the experience their students would have.

Final Thoughts

This study focused on the quantitative data comparing posttest scores between control and treatment groups. While this study was 100% quantitative, some qualitative themes emerged through this study. One discovery from the literature review from Chapter 2 of this study was the fact that there are topics of the CCA curriculum that require students to learn and execute Algebra in a conceptual way. To create an environment that is conducive to conceptual learning, it is necessary for teachers to use technology innovations (such as the TI-Nspire) as a tool for student learning. All too often, technology tools can be used simply for the sake of using technology. This limits the learning experience of the student and prevents the learning tool from doing what it was designed to do. One way to prevent this from happening is by providing consistent and ongoing professional learning for teachers who will be utilizing the technology. This includes TI-Nspire technology, but is not limited to them. This accounts for any technology learning innovation in existence and that have yet to be created.

Summary

This study was conducted for the purpose of comparing Common Core Algebra (CCA) courses that do not use TI-Nspire technology to CCA courses that use TI-Nspire technology. All data collected was quantitative in the means of a pretest and a posttest. Ninth grade CCA students made up the 116 sample participants. This inquiry was conducted during the 2014-2015 school year. The major findings noted that the means of the pretest scores were statistically equivalent while the means of the posttest score were statistically different. The finding suggests that the use of TI-Nspire technology in CCA classrooms is a benefit to students.

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Appendix A

The Pretest

Mathematics Chart

LENGTH	CAPACITY AND VOLUME
Metric 1 kilometer = 1000 meters 1 meter = 100 centimeters 1 centimeter = 10 millimeters **Customary** 1 mile = 1760 yards 1 mile = 5280 feet 1 yard = 3 feet 1 foot = 12 inches	**Metric** 1 liter = 1000 milliliters **Customary** 1 gallon = 4 quarts 1 gallon = 128 ounces 1 quart = 2 pints 1 pint = 2 cups 1 cup = 8 ounces
MASS AND WEIGHT	**TIME**
Metric 1 kilogram = 1000 grams 1 gram = 1000 milligrams **Customary** 1 ton = 2000 pounds 1 pound = 16 ounces	1 year = 365 days 1 year = 12 months 1 year = 52 weeks 1 week = 7 days 1 day = 24 hours 1 hour = 60 minutes 1 minute = 60 seconds

Mathematics Chart

PERIMETER		AREA	
square	$P = 4s$	square	$A = s^2$
rectangle	$P = 2\ell + 2w$ or $P = 2(\ell + w)$	rectangle	$A = \ell w$ or $A = bh$
		triangle	$A = \frac{1}{2}bh$ or $A = \frac{bh}{2}$
		trapezoid	$A = \frac{1}{2}(b_1 + b_2)h$ or $A = \frac{(b_1 + b_2)h}{2}$
		circle	$A = \pi r^2$

CIRCUMFERENCE

circle $C = 2\pi r$ or $C = \pi d$

B *represents the area of the base of a solid figure.*

P *represents the Perimeter of the Base of a three-dimensional figure.*

VOLUME		SURFACE AREA	
cube	$V = s^3$	cube (total)	$S = 6s^2$
retangular prism	$V = \ell wh$ or $V = Bh$	prism (lateral)	$S = Ph$
		prism (total)	$S = Ph + 2B$
triangular prism	$V = Bh$	pyramid (lateral)	$S = \frac{1}{2}P\ell$
cylinder	$V = \pi r^2 h$ or $V = Bh$	pyramid (total)	$S = \frac{1}{2}P\ell + B$
		cylinder (lateral)	$S = 2\pi rh$
cone	$V = \frac{1}{3}\pi r^2 h$ or $V = \frac{1}{3}Bh$	cylinder (total)	$S = 2\pi rh + 2\pi r^2$ or $S = 2\pi r(h + r)$

PI

$\pi \approx 3.14$ or $\pi \approx \frac{22}{7}$

PYTHAGOREAN THEOREM

$a^2 + b^2 = c^2$

SIMPLE INTEREST FORMULA

$I = prt$

Diagnostic and Placement Algebra 1

Name ____________________
Date ____________________

This test contains 30 multiple-choice questions. Work each problem in the space on this page. Select the best answer. Write the letter of the answer on the blank at the right.

1 Jake goes to the grocery store and buys 3 apples, 2 cans of soup, and 1 box of cereal. The apples cost \$0.89 each; the soup costs \$2.98 per can; and the box of cereal costs \$4.99. Write an equation that represents the total cost *c* of Jake's purchases. **1** ________

- **A** $c = (3 + 0.89) + (2 + 2.98) + 4.99$
- **B** $c = (3 + 0.89) \cdot (3 + 2.98) + 4.99$
- **C** $c = (3 \cdot 0.89) + (2 \cdot 2.98) + 4.99$
- **D** $c = (3 \cdot 0.89) \cdot (2 \cdot 2.98) \cdot 4.99$

2 Mr. Thomas wants to buy a boat. He must make 48 monthly payments to pay back the amount he borrowed, plus interest. His monthly payment is \$161.85. What other information is necessary to determine the amount of money Mr. Thomas borrowed from the bank? **2** ________

- **F** How much Mr. Thomas makes per month
- **G** The interest rate the bank charges
- **H** How much a boat license costs
- **J** How much the value of the boat will increase

3 Ricky jogs 5 laps around a track in 8 minutes. Which of the following would be the same number of laps per minute? **3** ________

- **A** 7 laps in 9.6 minutes
- **B** 10 laps in 15.6 minutes
- **C** 12 laps in 19.2 minutes
- **D** 8 laps in 20 minutes

4 The planet Mercury is about 5.80×10^7 kilometers from the Sun. Express this number in standard notation. **4** ________

- **F** 0.0000058
- **G** 0.00000058
- **H** 5,800,000
- **J** 58,000,000

5 Which of the following is equivalent to the expression $8^{-5} \times 8^2$? **5** ________

A $\frac{1}{8^7}$ **B** $\frac{1}{8^3}$ **C** 8^3 **D** 8^7

6 What is the solution of the equation? **6** ________

$$\frac{2}{5}(y + 10) = 8$$

F $y = -5$ **G** $y = 10$ **H** $y = 20$ **J** $y = 30$

7 What is the solution of the system of equations? **7** ________

$$y = 2x$$
$$y = x + 5$$

A (0, 5)
B $\left(1\frac{2}{3}, 6\frac{2}{3}\right)$
C (2, 7)
D (5, 10)

8 Barb walked 1.3 miles to her friend's house and then $\frac{3}{4}$ mile to the library. How far did Barb walk in all? **8** ________

F $1\frac{9}{40}$ miles
G $1\frac{3}{7}$ miles
H $2\frac{1}{20}$ miles
J $2\frac{1}{10}$ miles

9 Which of the following sets of numbers does $\sqrt{121}$ NOT belong? **9** ________

A integer
B real number
C rational number
D irrational number

10 What is the decimal expansion of $-\frac{11}{15}$? **10** ________

F $-0.7\overline{3}$
G $-0.\overline{73}$
H -0.73
J -0.7

11 Between which two numbers on a number line does $\sqrt{70}$ fall? **11** ________

A 6 and 7
B 7 and 8
C 8 and 9
D 9 and 10

12 Which of the following sets of numbers is correctly ordered from least to greatest? **12** ________

F $4.2, \sqrt{16}, 4\frac{1}{3}, \sqrt{18}$

G $4.2, \sqrt{16}, \sqrt{18}, 4\frac{1}{3}$

H $\sqrt{16}, 4.2, 4\frac{1}{3}, \sqrt{18}$

J $\sqrt{16}, 4.2, \sqrt{18}, 4\frac{1}{3}$

13 Which algebraic expression can be used to find the *n*th term in the following sequence? **13** ________

6,10,14,18,22,...

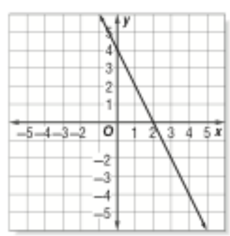
A $n + 4$ **B** $6n + 4$ **C** $6n$ **D** $4n + 2$

14 Which of the following is not a linear function? **14** ________

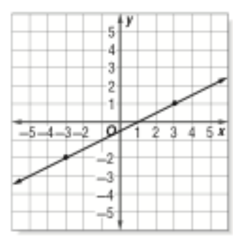
F $y = \frac{1}{3}x - 2$

H $y = 2x^2$

G



J



15 Mrs. Junkin wrote the function $f(x) = \frac{2}{3}x - 5$ on the chalkboard. What is the value of this function for $f(6)$? **15** ________

A −1 **B** 1 **C** 7 **D** 9

16 Which best describes the graph of the function $f(x) = -5x$? **16** ________

F A straight line through the origin with a steep slope upward to the right.

G A straight line through the origin with a steep slope downward to the right.

H A straight line through −5 on the *x*-axis with a slope downward to the right.

J A straight line through −5 on the *y*-axis with a slope upward to the right.

17 Which function described below has the greatest rate of change? **17** ________

I $f(x) = 5x + 7$

II $f(x) = \frac{1}{3}x - 1$

III

x	$f(x)$
1	4
2	8
3	12
4	16

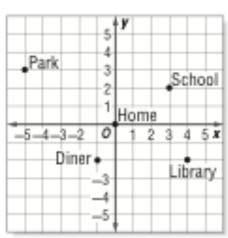
A I
B II
C III
D They all have the same rate of change.

18 What is the slope of the function described in the table below? **18** ________

x	y
0	−3
2	−2
4	−1
6	0

F −3 **G** $\frac{1}{2}$ **H** 2 **J** 3

19 Robin's neighborhood is mapped out on the graph below. Each unit on the map represents 1 mile. **19** ________



About how far apart are the park and diner?

A about 4 miles
B about 5 miles
C about 6.4 miles
D about 10 miles

20 Jason is experimenting with different ramps to replace the stair step into his house. The table below shows the measure of a given angle *m* and its complement.

20 ________

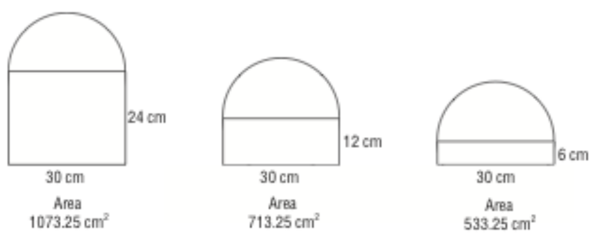
Measure of ∠*m*	Measure of ∠*m*'s Complement
5°	85°
15°	75°
25°	65°
35°	55°
45°	45°

Based on the table, which of the following statements is true?

F As the measure of ∠*m* decreases, its complement decreases by 10 degrees.
G ∠*m* and its complement form an acute angle.
H The sum of the measures of ∠*m* and its complement is 90.
J Subtracting 45 from the measure of ∠*m* will determine its complement.

21 The following figures are formed using a semicircle and a rectangle.

21 ________

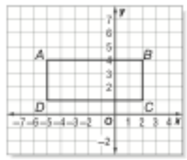


Based on this pattern, what will be the area of the next figure?

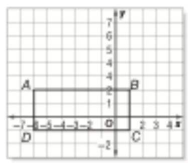
A 266.625 cm^2 because the next figure will decrease in area by $\frac{1}{2}$ the previous figure.
B 173.25 cm^2 because the next figure will decrease in area by 360 cm^2.
C 353.25 cm^2 because the next figure will decrease in area by 180 cm^2.
D 443.25 cm^2 because the next figure will decrease in area by 90 cm^2.

22 Rectangle *ABCD* is shown on the coordinate grid below. Which of the following graphs represent the translation of Rectangle *ABCD* over the following: $(x, y) \rightarrow (x-2, y+1)$?

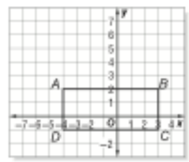
22 ________



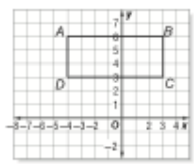
F



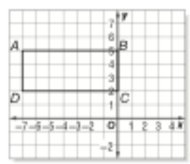
H



G



J



23 A photo with a length of 4 inches and a width of 6 inches is enlarged to fit in a large picture frame. The photo and the enlarged picture are similar. The length of the enlarged picture is 14 inches. What is the width of the enlarged picture?

23 ________

A 9.3 inches **C** 21 inches

B 14 inches **D** 56 inches

24 The lengths of the sides of a right triangle are 9 centimeters and 40 centimeters. What is the length of the hypotenuse?

24 ________

F 31 centimeters **H** 49 centimeters

G 41 centimeters **J** 81 centimeters

29 The scatter plot below shows the yearly advertising expenditures and the relative sales for a small company. Which of the following statements is true? **29** ________

A A line of best fit can be drawn from the origin with a slope going upward to the right.

B A line of best fit can be drawn vertically from an expenditure of $1500.

C A line of best fit can be drawn horizontally from a sales of $125,000.

D The data has no correlation, so a line of best fit cannot be drawn.

30 The frequency table below shows the test scores for Mr. Cortez's English class. What is the relative frequency for a test score of 81–90%? **30** ________

Test Scores		
Score (%)	**Tally**	**Frequency**
91–100	卌 |	6
81–90	卌 |||	8
71–80	卌	5
61–70	|||	3

F $\frac{3}{11}$ **G** $\frac{3}{10}$ **H** $\frac{4}{11}$ **J** $\frac{2}{5}$

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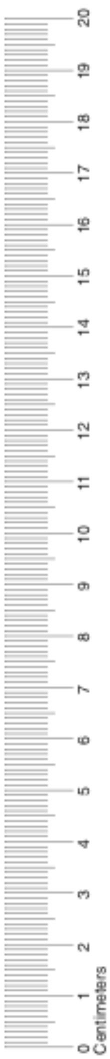
71–80	𝍸	5
61–70	|||	3

F $\frac{3}{11}$ **G** $\frac{3}{10}$ **H** $\frac{4}{11}$ **J** $\frac{2}{5}$

Appendix B

The Posttest

Mathematics Chart



LENGTH	**CAPACITY AND VOLUME**
Metric	**Metric**
1 kilometer = 1000 meters	1 liter = 1000 milliliters
1 meter = 100 centimeters	
1 centimeter = 10 millimeters	**Customary**
	1 gallon = 4 quarts
Customary	1 gallon = 128 fluid ounces
1 mile = 1760 yards	1 quart = 2 pints
1 mile = 5280 feet	1 pint = 2 cups
1 yard = 3 feet	1 cup = 8 ounces
1 foot = 12 inches	
MASS AND WEIGHT	**TIME**
Metric	1 year = 365 days
1 kilogram = 1000 grams	1 year = 12 months
1 gram = 1000 milligrams	1 year = 52 weeks
	1 week = 7 days
Customary	1 day = 24 hours
1 ton = 2000 pounds	1 hour = 60 minutes
1 pound = 16 ounces	1 minute = 60 seconds

Mathematics Chart

PERIMETER

rectangle	$P = 2\ell + 2w$ or $P = 2(\ell + w)$

CIRCUMFERENCE

circle	$C = 2\pi r$ or $C = \pi d$

AREA

rectangle	$A = \ell w$ or $A = bh$
triangle	$A = \frac{1}{2}bh$ or $A = \frac{bh}{2}$
trapezoid	$A = \frac{1}{2}(b_1 + b_2)h$ or $A = \frac{(b_1 + b_2)h}{2}$
regular polygon	$A = \frac{1}{2}aP$
circle	$A = \pi r^2$

B *represents the area of the base of a solid figure.*

P *represents the Perimeter of the Base of a three-dimensional figure.*

SURFACE AREA

cube (total)	$S = 6s^2$
prism (lateral)	$S = Ph$
prism (total)	$S = Ph + 2B$
pyramid (lateral)	$S = \frac{1}{2}P\ell$
pyramid (total)	$S = \frac{1}{2}P\ell + B$
cylinder (lateral)	$S = 2\pi rh$
cylinder (total)	$S = 2\pi rh + 2\pi r^2$ or $S = 2\pi r(h + r)$
cone (lateral)	$S = \pi r\ell$
cone (total)	$S = \pi r\ell + \pi r^2$ or $S = \pi r(\ell + r)$
sphere	$S = 4\pi r^2$

VOLUME

prism or cylinder	$V = Bh$
pyramid or cone	$V = \frac{1}{3}Bh$
sphere	$V = \frac{4}{3}\pi r^3$

SPECIAL RIGHT TRIANGLES

30°, 60°, 90°	$x, x\sqrt{3}, 2x$
45°, 45°, 90°	$x, x, x\sqrt{2}$

PYTHAGOREAN THEOREM

$a^2 + b^2 = c^2$

DISTANCE FORMULA	$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$
SLOPE OF A LINE	$m = \frac{y_2 - y_1}{x_2 - x_1}$
MIDPOINT FORMULA	$M = \left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2}\right)$
QUADRATIC FORMULA	$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
SLOPE-INTERCEPT FORM OF AN EQUATION	$y = mx + b$
POINT-SLOPE FORM OF AN EQUATION	$y - y_1 = m(x - x_1)$
STANDARD FORM OF AN EQUATION	$Ax + By = C$
SIMPLE INTEREST FORMULA	$I = prt$

Diagnostic and Placement Geometry

Name ______________________
Date ______________________

This test contains 30 multiple-choice questions. Work each problem in the space on this page. Select the best answer. Write the letter of the answer on the blank at the right.

1 Carla earns $9 per hour working at a clothing store. She is writing a function to show the relationship between her hours worked *h*, and her wages earned *w*. In Carla's function, what does the independent variable represent? **1** ________

A the number of hours worked
B the wage earned in one hour
C the total wages earned
D the amount of time Carla must work to earn $1

2 Which statement describes each ordered pair (x, y) in the table? **2** ________

x	0	2	4	6
y	−2	2	14	34

F y is 2 less than x.
G y is equal to x.
H y is 2 less than twice x.
J y is 2 less than the square of x.

3 Which function describes the data in the table? **3** ________

x	0	1	2	3
y	3	5	7	9

A $y = x + 3$
B $y = 2x + 3$
C $y = 3x$
D $y = 3x - 1$

4 What is the domain of the function $f(x) = \frac{3}{x+2}$? **4** ________

F the set of all real numbers
G the set of all real numbers except $x = -2$
H the set of all real numbers except $x = 0$
J the set of all real numbers except $x = 2$

5 The table below defines a linear function. What is the slope of the line?

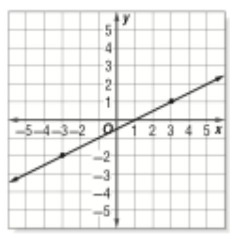
5 ________

x	y
4	7
2	3
0	−1
−2	−5
−4	−9

A $\frac{1}{2}$ **B** 2 **C** $\frac{7}{4}$ **D** $\frac{11}{5}$

6 Which statement is NOT true for the graph below?

6 ________



F The x-intercept is 1.
H The slope is $\frac{1}{2}$.
G The y-intercept is $-\frac{1}{2}$.
J The line contains the origin.

7 A student graphed the line $y = 3x + 2$ plotting and connecting points A, B, and C. How can the student use points A, B, and C to find the graph of $y = 3x - 5$?

7 ________

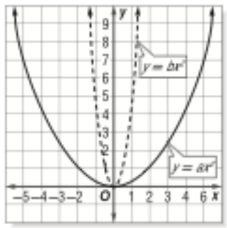
A Move each point down 5 units.
B Move each point down 7 units.
C Move each point left 3 units.
D Move each point right 7 units.

8 What is the range of the function $f(x) = 3x^2 - 7$?

8 ________

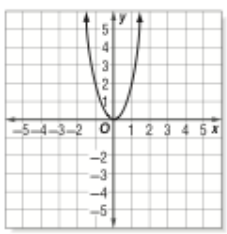
F $y \geq 7$ **G** $y \leq 7$ **H** $y \geq -7$ **J** $y \leq -7$

9 The graph of $y = ax^2$ and $y = bx^2$ are shown below. Which statement describes the relationship between a and b? **9** ________



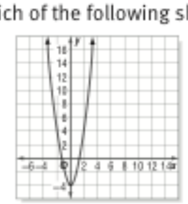
A $a = b$
B $a > b$
C $a < b$
D There is not enough information to determine the relationship.

10 The graph of $y = 2x^2$ is shown below. **10** ________

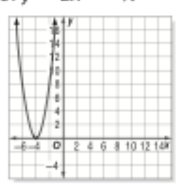


Which of the following shows the graph of $y = 2x^2 - 4$?

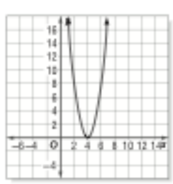
F



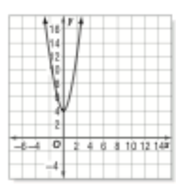
H



G



J



11 The health club charges a $75 membership fee plus a $40 monthly fee. Wesley has $300 to spend on a health club membership. Which inequality can be used to find m, the number of months for which Wesley can afford to be a member of the health club?

11 ________

A $300 \geq 75 + 40m$

B $300 \leq 75m + 40$

C $300 \leq 75 + 40m$

D $300 \geq 75m + 40$

12 The number of cars sold in May m was 60 less than four times the number of cars sold in April a. Which equation shows the relationship between m and a?

12 ________

F $m = a - 60$

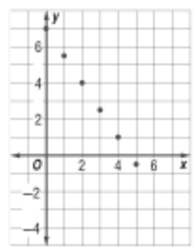
G $m = 60 - 4a$

H $m = a^4 - 60$

J $m = 4a - 60$

13 The graph below shows several ordered pairs for a linear function.

13 ________



Which is the best prediction of the value of y when x is 7?

A −1.5 **B** −2 **C** −2.5 **D** −3.5

14 Solve for x.
$12 - 14x = -72$

14 ________

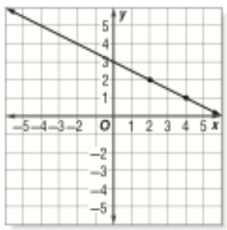
F −36

G −6

H 36

J 6

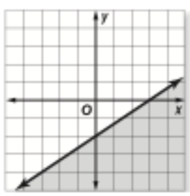
15 The graph shows part of the line $y = -\frac{1}{2}x + b$. What is the value of b? **15** ________



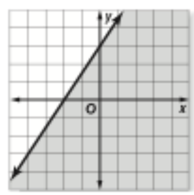
A $-\frac{1}{2}$ **B** 2 **C** 3 **D** 6

16 In which graph does the shaded area show the solutions to the inequality $3x - 2y \le -6$? **16** ________

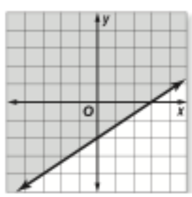
F



H



G



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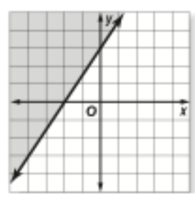


17 Which is NOT a reasonable solution to the inequality $2x \ge x$? **17** ________

A $x = -1$ **B** $x = 0$ **C** $x = 1$ **D** $x = 2$

18 Molly has \$5.20 in dimes and quarters. The number of dimes is 3 more than the number of quarters. Which system of linear equations can be used to find d, the number of dimes, and q, the number of quarters?

18 ________

F $3q + d = 5.20$
$q + d = 0.35$

G $d = 3 + q$
$0.10d + 0.25q = 5.20$

H $(q + 3) + q = 5.20$
$q + d = 0.35$

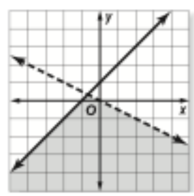
J $q = 3 + d$
$0.10d + 0.25q = 5.20$

19 Which shows the solution set of the following system of inequalities?

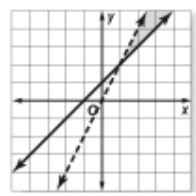
19 ________

$$x - y \leq -1$$
$$x + 2y < 0$$

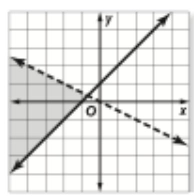
A



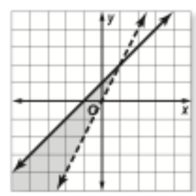
C



B



D



20 What are the solutions to the equation $2x^2 + 9x = 5$?

20 ________

F $x = -1, x = \frac{5}{2}$

H $x = 5, x = -\frac{1}{2}$

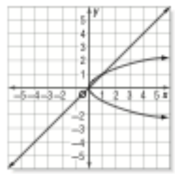
G $x = 1, x = -\frac{5}{2}$

J $x = -5, x = \frac{1}{2}$

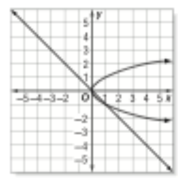
21 Which of these shows the graphs of $y = x$ and $y = x^2$?

21 ________

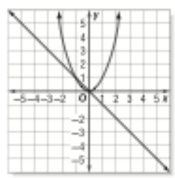
A



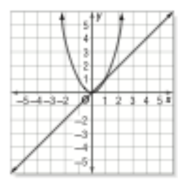
C



B

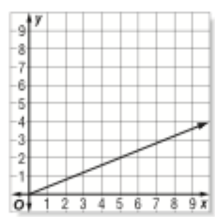


D



22 Which relationship is best shown by the graph?

22 ________



F Oranges cost $0.50 per pound.
G A tree grows 2 inches every 5 months.
H The temperature of a cooler decreases 4 degrees every 10 minutes that it is open.
J A pool's water level increases at 5 gallons per minute.

23 Which algebraic expression represents the phrase "6 less than the sum of x and the square of x?"

23 ________

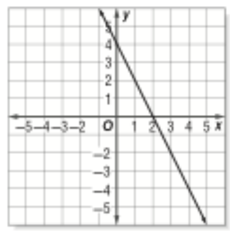
A $x + x^2 - 6$
C $6 - x + x^2$
B $x + \sqrt{x} - 6$
D $6 - (x + x^2)$

24 Which expression is equivalent to $-3(8 - 10)$?

24 ________

F $-24 - 30$
H $-24 + 30$
G $-24 - 10$
J $24 - 30$

25 What is the equation of the line shown? **25** ________



A $y = -2x + 4$ C $y = -2x - 4$
B $y = 4x - 2$ D $y = 4x + 2$

26 Which is an equation of the line that has a slope of $-\frac{1}{3}$ and passes through the point $(-5, 2)$? **26** ________

F $x - 3y = -11$ H $x + 3y = 1$
G $x - 3y = 11$ J $x + 3y = 21$

27 The weight of an object on the moon varies directly as its weight on earth. The constant of variation is 6. Which equation describes this relationship? **27** ________

A $y = 6x$ C $xy = 6$
B $y = x + 6$ D $x + y = 6$

28 Adam bought CDs for $18 each and T-shirts for $11 each. Altogether, he spent $105. Which equation best represents Adam's purchase? **28** ________

F $4c + 3t = 105$ H $29ct = 105$
G $18c + 11t = 105$ J $(18 + 11)(c + t) = 105$

29 Simplify $\frac{\sqrt{a} \cdot b^2}{a^{\frac{3}{2}} b^5}$. **29** ________

A $a^{\frac{1}{3}}b^{\frac{2}{5}}$ C $\frac{1}{ab^3}$

B $a^{\frac{3}{4}}b^{10}$ D $\frac{1}{a^{\frac{1}{4}}b^3}$

30 Which relationship would most likely have a negative correlation? **30** ________

F the time elapsed, and the number of words typed
G the temperature outside, and the number of people wearing coats
H the number of students in a school, and the number of teachers in the school
J the rate at which a car is driven, and the number of miles driven in one hour

Appendix C

Email to student research participants (and parent / guardians)

Dear __________,

I am contacting you to ask that you participate in a research study entitled "The Effect Of The TI-Nspire On Student Achievement in Common Core Algebra." The research is being conducted as part of my coursework through the Concordia University of Chicago. The Institutional Review Board-Human Subjects in Research, Concordia University of Chicago, will review this research study. The purpose of this quantitative experimental research is to compare Common Core Algebra (CCA) courses that do not use TI-Nspire technology to CCA courses that use TI-Nspire technology for CCA students at Great Neck Schools. If you choose to participate, your pretest and posttest scores will be compared to other students in CCA.

There are several key elements that I would like you to consider in regard to this request for your voluntary participation in the research project. Your choice to participate in the study or not will have no bearing on your grades earned on your report card in CCA. There will be no repercussions based on participating or not participating in this research study. The completed research will be shared with the University, however the anonymity of research participants will remain 100% confidential. You will not be individually surveyed or questioned. Only the pre and posttest scores will be used for analysis.

The attached Consent Form further outlines important elements related to your potential participation. Please respond via email if you have any questions about the study, including issues of anonymity or expectations of research participants. If you choose to participate, please reply to this email with a confirmation within five days of today. At that point, we will set up a time to meet so that I can answer any questions and clarify the requirements and expectations for participation in the study. The attached Consent Form has been included only for you and your parent / guardian's reference. If you elect to participate in this study, you and your parent/guardian must sign the Consent to Participate Form.

A hard copy of this email will be provided to you to give to your parent / guardian. If you do not reply to this email or the hard copy of the email, then you will not be contacted any further in regard to this research project.

Warmest Regards,

Paul Alan Pelech

Appendix D

The effect of the TI-Nspire on student achievement in Common Core Algebra

My name is Paul Pelech and I am a doctoral candidate at Concordia University Chicago. I am conducting research on the effect (if any) of TI-Nspire technology in regards to Common Core Algebra (CCA). The purpose of this form is to explain the research process and your potential participation in this research.

Research Process:

• Review and analysis of pretest data.

• Review and analysis of posttest data.

• You are being asked to participate in a research study entitled "The Effect Of The TI-Nspire On Student Achievement in Common Core Algebra" because as a CCA student, you have a valuable perspective as someone who is experiencing CCA. The purpose of this quantitative experimental research is to compare Common Core Algebra (CCA) courses that do not use TI-Nspire technology to CCA courses that use TI-Nspire technology for CCA students at Great Neck Schools.

• The research study will be conducted during the Spring 2015 semester. During that time, participants will complete a pretest and a posttest.

• The participants of the study will remain strictly confidential. Records of interviews or observations will remain confidential and will be destroyed within 12 months of completion of the research. Legally authorized agencies, including the Concordia University Chicago Institutional Review Board, have the right to review research records. When reporting the results of this research project, your name or any other personally identifying information will not be used. Your name will not be recorded, as well as any identifying information in notes or in any documentation resulting from this research. You will be assigned a pseudonym that will be used to represent your data.

• There is little or no risk to you in participating in this project. However, if you become uncomfortable or stressed while completing the pre and/or posttest, you can inform me and opt out of the study at any time. There will be no negative consequences if you elect to opt out at any time. Participation in this research study is strictly voluntary.

• No compensation or medical treatments are available if an injury occurs as a result of participating in this research study.

• If you have any questions about this project, please contact Paul Pelech. Paul Pelech can be reached by phone at (516) 234-5480 or via email at crf_pelechpa@cuchicago.edu. You (or your parent / guardian) can also contact Dr. Paul Sims, the chairperson of my committee by phone at (773) 552-2591 or via email at paul.sims@cuchicago.edu.

• This research study has been reviewed by the Institutional Review Board-Human Subjects in Research, Concordia University of Chicago. For research-related problems or questions regarding subjects' rights, you can contact the Concordia University Chicago Institutional Review Board by phone at (708) 209-3159 or by e-mail at IRB@CUChicago.edu.

Appendix E

Consent Form for "The Effect Of The TI-Nspire On Student Achievement in Common Core Algebra

The preceding pages of the Consent Form may be retained for your records.
The researcher, Paul Pelech, will retain this page.

Participant's Name (Print):

____

Parent / Guardian's Name (Print):

____

PLEASE INITIAL:

___ I AGREE to participate in the research study "The Effect Of The TI-Nspire On Student Achievement in Common Core Algebra"

___ I DO NOT AGREE to participate in the research study "The Effect Of The TI-Nspire On Student Achievement in Common Core Algebra"

Participant's Signature:

____

Parent / Guardian's Signature:

____

Date: ____________________________

Appendix F

Email to prospective teacher research participants

Dear __________,

I am contacting you to ask that you participate in a research study entitled "The Effect Of The TI-Nspire On Student Achievement in Common Core Algebra." The research is being conducted as part of my coursework through the Concordia University of Chicago. The Institutional Review Board-Human Subjects in Research, Concordia University of Chicago, will review this research study. The purpose of this quantitative experimental research is to compare Common Core Algebra (CCA) courses that do not use TI-Nspire technology to CCA courses that use TI-Nspire technology for CCA students at Great Neck Schools. If you choose to participate, your pretest and posttest scores from the CCA students you teach participating in this study will be compared to other students in CCA.

There are several key elements that I would like you to consider in regard to this request for your voluntary participation in the research project. Your choice to participate in the study or not will have no bearing on your evaluation as a teacher, nor will your findings be shared with school administration. There will be no repercussions based on participating or not participating in this research study. The completed research will be shared with the University, however the anonymity of research participants will remain 100% confidential. You will not be individually surveyed or questioned. Only the pre and posttest scores will be used for analysis.

The attached Consent Form further outlines important elements related to your potential participation. Please respond via email if you have any questions about the study, including issues of anonymity or expectations of research participants. If you choose to participate, please reply to this email with a confirmation within five days of today. At that point, we will set up a time to meet so that I can answer any questions and clarify the requirements and expectations for participation in the study. The attached Consent Form has been included only for your reference. If you elect to participate in this study, you must sign the Consent to Participate Form.

A hard copy of this email will be provided to you for your records. If you do not reply to this email or the hard copy of the email, then you will not be contacted any further in regard to this research project.

Warmest Regards,

Paul Alan Pelech

Appendix G

Vitae

Name:	Paul Alan Pelech
Date of Birth:	July 31, 1975
High School:	Mineola High School Garden City Park, New York Graduated: 1993
Associates Degree:	Associate of Science State University of New York at Farmingdale Farmingdale, New York 1995
Baccalaureate Degree:	Bachelor of Business Administration Embry-Riddle Aeronautical University Prescott, Arizona 1997
Other Degrees:	Master of Science St. John's University Jamaica, New York 2005
	Master of Education The College of St. Rose Albany, New York 2008