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Increased personalization through the use of technology in the secondary mathematics classroom

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ABSTRACT

INCREASED PERSONALIZATION THROUGH THE USE OF TECHNOLOGY IN THE SECONDARY MATHEMATICS CLASSROOM

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This quantitative non-experimental dissertation explores the impact of disruptive innovation theory in the form of computer-enhanced instruction (CEI) upon mathematics achievement. It also examines both teacher and student perceptions of CEI implementation in high school mathematics classrooms and the impacts of CEI upon student mathematics achievement. The study includes two cohorts of ninth-grade students in a suburban public high school district located southwest of Chicago, Illinois. The study spanned the 2013-2014 and 2014-2015 school years. The first student cohort was the pre-intervention or control group and included students who were enrolled in Algebra 1, Honors Algebra 1, or Algebra 1 Support during the 2013-2014 school year. The second student cohort was the intervention group comprised of students who were enrolled in Algebra 1, Honors Algebra 1, or Algebra 1 Support during the 2014-2015 school year.

This study did not find CEI to have a statistically significant impact upon student mathematics achievement. However, the study used a survey to gather self-reported teacher data and this data was used to categorize teachers into either a high-use or low-use CEI group. Teachers in the high-use group demonstrated a statistically significant higher mean change score for student achievement.

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INCREASED PERSONALIZATION THROUGH THE USE OF TECHNOLOGY IN THE SECONDARY MATHEMATICS CLASSROOM

BY

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DEDICATION

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CHAPTER ONE

INTRODUCTION

Introduction

The early 1900s brought about a major shift in how the public viewed education. Education transitioned from being viewed as a privilege for an affluent few to being regarded as a necessity needed for all to ensure the nation's progress. Today, policy makers continue to look to the educational system to solve many of society's tribulations. Though the current U.S. educational system has changed since the 1900s, many of today's learning structures and practices would be recognizable to students educated in the early to mid-19th century (Horn, 2010; Keller, Bonk & Hew, 2005). At that time the country was in a chaotic state because the industrial age required a different type of worker than the agrarian society of the past. Policy makers sought to solve this problem through public education, basing their educational policies on the existent factory model rooted on efficiency and productivity. Horn (2010) stated:

> Americans asked public education to prepare everyone for a vocation in the industrial age of factories and Frederick Taylor's time-and-motion studies. To do this, the school system changed gears and began extending high school to everyone. (p. 1)

As a result, the one-room schoolhouse was transformed into a more structured instructional system where students were placed in age-specific grades designed to facilitate the teacher's ability to focus on just one set of students with similar academic proficiencies (Horn, 2010; Keller et al., 2005). In many respects this structure resembled a factory assembly line.

Under this configuration, students were "processed in batches," with teachers teaching students the same subject in the same way and at the same pace (Horn, 2010, p. 35). This standardization of education has continued over the past century, surviving the creation of additional federal and state directives such as the *No Child Left Behind* (NCLB) legislation and the adoption of the *Common Core State Standards* (CCSS) (Tyack & Cuban, 1995; National Commission on Excellence in Education, 1983; National Research Council, 1989). NCLB set forth explicit requirements for the academic accountability structure state and local school officials were directed to utilize (Dee & Jacob, 2010). The CCSS prescribed what students should know and be able to do at certain points in time. However, these federal dictates provided little guidance on effective pedagogical practices and learning environments (Allen, Bassiri & Noble, 2009; NCTM, 1989, 2000). Thus policy makers have continued to formulate legislation focused on "what" is being taught. Though many of these initiatives have brought about positive changes, adequate attention has not been focused on changing "how" students are taught (Cuban, 2012). Policy makers' have generally not focused on pedagogical classroom practices. As a result, 21^{st}-century curricular content is being taught using 19^{th}-century pedagogy.

For decades concerns regarding mathematics achievement have been central to national reform initiatives (National Commission on Excellence in Education, 1983; National Research Council, 1989; NCTM, 1989, 2000; National Mathematics Advisory Panel, 2008; Daun-Barnett & St. John, 2012). As a result, mathematics requirements for students have increased with many states requiring three to four years of mathematics courses for high school graduation (Zelkowski, 2010). Though this was an important step, these changes continued to focus on what students should know and be able to do in order to receive a high school diploma; not on how mathematical skills and concepts were taught. As the number of students going to college has increased and additional mathematics course requirements were added to the high school curriculum, many students have struggled to demonstrate mastery of the additional mathematics curricular components (Daun-Barnett & St. John, 2012; U.S. Department of Education, 2014). Therefore, today a continued focus on increasing the proportion of students who are college and career ready in the area of mathematics is vitally important.

Computer-Enhanced Instruction Can Influence Students' College and Career Readiness

Educational leaders in the 21st century must determine how student academic achievement can be maximized with fewer teachers, more students, and less financial support. One potential answer is leveraging the use of technology to transform current public school learning structures.

Traditional learning structures do not work for all students (Pritchett, Pritchett, & Wohleb, 2013; Christensen, Horn, & Johnson, 2011; Christensen, Horn, & Staker, 2013; Horn, 2010; Horn & Staker, 2012; Sheninger, 2016). Therefore, adopting innovative virtual learning systems such as a blended learning model may increase student academic achievement and engagement (Bailey et al., 2013; Christensen et al., 2011; Christensen et al., 2013; Horn, 2010; Horn & Staker, 2012; Fuel Education, 2014). Blended learning is a learning structure designed to engage students in both remote or online learning as well as face-to-face instruction.

Implementing personalized learning structures through flexible learning pedagogies may enable educators to transform the teaching and learning process. In addition, this type of learning structure could yield higher academic productivity and create an educational environment more conducive to differentiation based upon individual student needs (Bailey et al., 2013; Christensen et al., 2011; Christensen et al., 2013; Horn, 2010; Horn & Staker, 2012; Rose & Rice, 2015). Along with the logistical changes needed to implement a successful blended learning initiative, strategic professional development and teacher preparation designed to effectuate major pedagogical shifts must also occur in order for increased student learning to be realized (Cuban, 2012; Keller, 2005).

Though schools are still expected to produce a skilled workforce, the skills needed by 21^{st}-century workers have changed (National Education Association, n.d.; Underwood & Banyard, 2008; National Mathematics Advisory Panel, 2008; Jones, 2008; Walters et al., 2014). Obedience and low-level skills are no longer the primary objectives. Today's employers are demanding workers who can problem-solve and think both independently and critically about organizational needs (Hodge & Lear, 2011; Jones, 2008). Many virtual learning advocates believe expanding the opportunities for online instruction is the type of disruptive innovation needed if the U.S. educational system will become better able to meet the needs of both students and the nation's workforce (Christensen et al., 2011; Christensen et al., 2013).

Theoretical Construct

The theoretical construct undergirding this study is Clayton Christiansen's disruptive innovation theory. Christiansen suggests there are two types of innovation: sustaining and disruptive. Sustaining innovations improve already existing products or processes in the marketplace while disruptive innovations redefine what is "good" in the marketplace (Christensen et al., 2011; Christensen et al., 2013). Christiansen asserts sustaining innovations are not bad; rather they are required for continual improvement.

Christiansen and colleagues' book, *Disrupting Class* (2011), applied disruptive innovation theory to education and postulated the traditional educational structures in most American schools were not producing student academic achievement commensurate with the nation's expectations. The authors suggested American schools needed to employ disruptive innovations in order to alter the trajectory of student academic performance. A specific disruptive innovation Christiansen et al. identified was leveraging technology to improve the personalization of instruction for students. For example, computer-enhanced instruction (CEI) may be implemented through a blended learning structure. In this structure students engage in a blend of remote or online learning experiences in concert with face-to-face classroom instruction. While online learning is not a new concept, pairing of virtual learning tools with face-to-face instruction is considered a disruptive innovation in K-12 school classrooms (Christensen et al., 2011; Christensen et al., 2013; Horn, 2010; Horn & Staker, 2012, 2014). This type of blended structure allows students to individually engage in meaningful learning activities while the teacher is working with smaller groups or other individual students. This structure allows for improved personalization and differentiation of instruction (Horn & Staker, 2014). This type of instruction is categorized as CEI because the teacher is still an integral part of the instructional process (Cuban & Kirkpatrick, 1998).

Problem Statement

Improving student mathematics achievement continues to be a concern. According to the National Assessment of Education Progress (NAEP) (p. 113) between 1973 and 2012 improvement in student mathematics achievement occurred at ages nine and thirteen. However, this trend has not yet been realized for older learners. Internationally, the Program for International Student Assessment (PISA) showed 29 other countries' education systems achieved higher average mathematics literacy scores than the United States. Additionally, the percentage of top U.S. students was lower than the average of countries comprising the Organization for Economic Cooperation and Development (OECD) (U.S. Department of Education, 2012). With more rigorous mathematics course sequences being mandated and implemented nationwide, public school leaders need to determine how to ensure students master the additional mathematical concepts and skills within the curriculum. This is because achievement gaps among and between various student subgroups continue to exist (U.S. Department of Education, 2012, 2014).

Ensuring students are college and career ready in the area of mathematics continues to be a primary focus in all U.S. schools. However, according to the National Council of Teachers of Mathematics (NCTM, 2000), “The quality of mathematics teaching is highly variable” and “there is no question that the effectiveness of mathematics education in the United States can be improved substantially.” Research on the relationship between CEI delivered in a blended learning structure and student college and career readiness in the area of mathematics must be conducted to determine if this type of learning structure has a positive impact on student mathematics achievement. To date, the effectiveness of blended learning environments, including hybrid structures in mathematics courses, has not been adequately researched (Cavalluzzo, Lowther, Mokher, & Fan, 2012; U.S. Department of Education, 2010; Picciano, 2009). Additionally, there is little research on whether a relationship exists between CEI and secondary student mathematics achievement. Also, relatively few studies involving the effectiveness of K-12 blending learning have been published (Chandler, Park, Levin & Morse, 2013; Halverson, Graham, Spring, & Drysdale, 2012; Means, Toyama, Murphy & Baki, 2013). There is also limited guidance for school leaders on the types of teacher professional development that has been shown to positively impact student mathematics proficiency (Gersten, Taylor, Keys, Rolfhus & Newman-Gonchar, 2014). The current study is designed to provide school officials with additional data needed to make both pedagogical and financial decisions.

Purpose

The current study's purpose is to examine the application of disruptive innovation theory in high school mathematics classrooms to determine CEI's impact on student mathematics achievement. In addition, the study examines both teacher and student perceptions of CEI implementation in high school mathematics classrooms.

Significance of the Study

Current legislation makes school boards, superintendents, principals, and teachers responsible for ensuring all students attain high academic standards. According to the National Mathematics Advisory Panel (2008), there is an urgent need to conduct research on the effectiveness of both small and large scale support-focused interventions in reducing the achievement gaps between White, Black, and Hispanic, and mid/high and low income student populations.

It is expected all K-12 public school students will complete a rigorous sequence of study in mathematics, resulting in students graduating from high school with minimally credits in Algebra 1, Geometry, and Algebra 2. Therefore, educators need to determine how to best meet the diverse needs of students entering high school with various pre-cursory mathematical concepts and skills mastered. There are various applications available offering personalized learning for students. However, these applications can be costly. Technology costs also include the time and cost of professional development needed for successful implementation. The current study seeks to determine whether CEI implementation with ninth-grade students yields improved mathematics achievement.

Research Questions

The following overarching question guided the current study: What is the relationship between computer-enhanced instruction (CEI) and student academic achievement? The following specific research questions also provided direction:

Research Question 1: Are there differences in the amount of student mathematics achievement growth between the control student group and the student treatment group receiving computer-enhanced instruction (CEI) as measured by the Educational Planning and Assessment (MATH EXPLORE) of ninth-grade Algebra 1 students?

Research Question 2: Are there differences in the amount of student mathematics achievement growth between the control student group and the student treatment group receiving computer-enhanced instruction (CEI) as measured by the Educational Planning and Assessment (MATH EXPLORE) of ninth-grade Honors Algebra 1 students?

Research Question 3: Are there differences in the amount of student mathematics achievement growth between the control student group and the student treatment group receiving computer-enhanced instruction (CEI) as measured by the Educational Planning and Assessment (MATH EXPLORE) of ninth-grade students who enter high school performing below grade level in mathematics?

Research Question 4: Are there differences in the amount of student mathematics achievement growth between Algebra 1 students whose teachers regularly utilize computer-enhanced instruction (CEI) as a pedagogy within their Algebra 1 course and students whose teachers who do not regularly use CEI within their Algebra 1 course as measured by the Educational Planning and Assessment (MATH EXPLORE)?

Research Question 5: Are there differences in the amount of student mathematics achievement growth between Algebra 1 students whose teachers self-report a positive perception of computer-enhanced instruction (CEI) and students whose teachers self-report a negative perception of CEI as measured by the Educational Planning and Assessment (MATH EXPLORE)?

Research Question 6: Are there differences in the amount of student mathematics achievement growth between Algebra 1 students whose teachers self-report a more student-centric instructional approach and students whose teachers self-report a less teacher-centric instructional approach as measured by the Educational Planning and Assessment (MATH EXPLORE)?

Definitions of Terms

Blended Learning refers to a learning structure characterized by students engaging in remote or online learning as well as face-to-face instruction (Picciano, 2009).

Computer Assisted Instruction (CAI) includes use of software programs, generally including tutorials or drill and practice (Cuban & Kirkpatrick, 1998).

Computer-Enhanced Instruction (CEI) is the use of technology applications or software designed to allow the teacher to serve as an integral part of instruction (Cuban & Kirkpatrick, 1998).

Computer Managed Instruction (CMI) includes tutorial and drill and practice, but also provides diagnostic applications and guidance for learning specific to the student (Cuban & Kirkpatrick, 1998).

Disruptive Innovation Theory is attributed to Clayton Christensen. The theory explains an innovation has the potential to transform an existing market or sector by introducing a new product or service that eventually redefines the industry (Christensen et al., 2011).

Educational Technology refers to a variety of technology-based programs or applications designed to deliver learning materials and support the learning process in K-12 classrooms to improve academic learning goals (Cheung & Slavin, 2013).

EXPLORE Assessment refers to the eighth and ninth-grade student assessment given as part of the Educational Planning and Assessment *(MATH EXPLORE)* series to assist educators in charting longitudinal student academic progress and to assist students in exploring career interests.

Station-Rotation Model is a blended learning model in which students and teachers meet during a scheduled class period within a school. However, in the blended learning model the teacher utilizes technology as a discrete instructional station within the classroom.

Personalization is the tailoring of instruction to meet the individual student's characteristics or preferences.

CHAPTER TWO

REVIEW OF THE LITERATURE

Organizational Framework of the Review of Literature

This chapter explores the research surrounding educational reform specific to mathematics and the use of technology in mathematics instruction. The study addresses the following questions: What is the current state of student mathematics achievement and associated educational reform initiatives? What is disruptive innovation theory and how can it be applied to high school mathematics instruction? How has technology been utilized to improve student academic achievement? How has technology been utilized to personalize classroom instruction? Most importantly, what innovative learning structures exist to improve student mathematics achievement?

The literature review illustrates while 21st-century high school students are expected to complete a more rigorous sequence of mathematics study, there have been minimal pedagogical shifts in high school mathematics instruction (Zelkowski, 2010; Daun-Barnett & St. John, 2012; U.S. Department of Education, 2014; NCTM, 2000). This literature review explores the limited existing research on the use of computer-enhanced instruction (CEI) in the high school mathematics classroom and CEI's impact on student achievement.

Mathematics Education Reform

Public school K-12 instructional leaders are charged with ensuring students are ready for the next academic level after high school graduation and, ultimately, ready to enter and be successful in either college or the workforce (Jones, 2008). Concern regarding student mathematics achievement has been central to national discussion for the last few decades. In 1989, the National Research Council published *Everybody Counts: A Report to the Nation on the Future of Mathematics Education*. This report indicated 75% of American students stopped studying mathematics before completing the prerequisite learning required for entry-level workforce jobs. A precursor to *Everybody Counts* was the governmental report, *A Nation at Risk* (National Commission on Excellence in Education, 1983). *A Nation at Risk* declared "our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world" (p. 112). *A Nation at Risk* further asserted the nation's public school system was to blame for this demise. *A Nation at Risk* served as a clarion call for immediate reform of the American educational system in an effort to improve performance of students in elementary, secondary, and post-secondary institutions by ensuring all students, especially disadvantaged students, had access to a rigorous curricula (National Commission on Excellence in Education, 1983).

At the time *Everybody Counts* and *A Nation at Risk* were issued, many high school students were able to opt out of studying either algebra or geometry because these courses were not required for high school graduation. In addition, over 25% of all high school students were dropping out of school before graduation. The dropout rate among Black, Hispanic and Native American students often exceeded 50% (National Research Council, 1989). *Everybody Counts* called for "equity and excellence," recommending national standards or a common core curriculum that was locally implemented as well as appropriate standards for mathematical assessment, requiring students to study mathematics every year they were in school (1989).

Mathematics achievement has continued to be a central focus in K-12 public schools, largely because mathematical skills are vitally important in the growing Science, Technology, Engineering and Math (STEM) fields (National Research Council, 1989; National Mathematics Advisory Panel, 2008; Benbow, 2012). Public perception that American students are not able to compete with students from other countries continues, especially in the area of mathematics (Musoba, 2010; U.S. Department of Education 2012, 2014).

Today the public continues to either expect the U.S. educational system to solve many of the nation's problems or blame the educational system for the existence of the problems. This is evidenced by policies such as NCLB and, most recently, the CCSS, both designed to close existing student academic achievement gaps by implementing a standardized national curriculum (Dee and Jacob; 2010; Tyrack & Cuban, 1995). These policies echoed the calls of *A Nation at Risk* (1983) and *Everybody Counts* (1989) calls for both improved student academic achievement and equity in education, meaning all students should have access to the same content knowledge and skill development regardless of the school they attend. As a result, in the area of mathematics reform, many states have instituted increased high school graduation requirements that minimally include the study of algebra and geometry in an effort to increase access to the concepts and skills taught within these courses to all students (Dounay, 2007; 2012). In addition, many states have enacted compulsory attendance laws to ensure more students attend school until, minimally, the ages of 16 and 17 (Dounay, 2007).

Student mathematics requirements have become more rigorous with many states requiring three or four years of mathematics as a requirement for high school graduation (Zelkowski, 2010). Today 17 states require four years of mathematics and this number will rise to at least 18 states for the 2020 graduating class (Dounay, 2012). Prior to the 2009 graduating class, Illinois required two years of mathematics and did not specify the required mathematics courses to be completed. Beginning with the class of 2009, Illinois required three years of mathematics for graduation, but again this expectation did not specify the courses necessary for fulfilling this requirement. Effective with the graduating class of 2010, Illinois began requiring three years of mathematics, i.e., “one Algebra 1 course and one unit that must include geometry content” (Dounay, 2007). Not only has Illinois increased high school graduation requirements with respect to the number of mathematics courses, there has also been increased guidance regarding both the content and skills taught in Illinois’ high school mathematics course sequence through the CCSS (Filson, Beedy, & Winters, 2013). As a result, school leaders must determine how to ensure students master these additional mathematical skills and concepts now required for high school graduation.

Disruptive Innovation Theory

Illinois’ increased graduation requirements in mathematics and the adoption of the CCSS strive to ensure continued access to the knowledge and skills learned through mathematics coursework, thus keeping schools on a path of continual improvement. However, according to the architect of disruptive innovation theory, the educational system requires a major change in order to meet current learner needs (Christensen et al., 2011).

Christensen’s (2011) research focused on the Strategic Management of Technology and Managing Innovation. Within the area of managing innovation, Christensen focused on elements causing organizations to either transform or fail to transform (Harvard Business School, n.d.; Christensen et al., 2011). Currently many of the concepts emerging from Christensen’s research are being applied in the public school setting. According to Christensen (2012), “a disruptive innovation is not a breakthrough innovation that makes good products a lot better, disruptive innovation transforms a product that historically was so expensive and complicated that only a few people with a lot of money and a lot of skill had access to it. The disruptive innovation makes it so much more affordable and accessible than a much larger population has access" (*Harvard Business Review*, podcast March 30, 2012).

Few policy initiatives have focused on the "how" of education or instructional pedagogy. Instead, initiatives have primarily focused on changing structures, changing what is being taught and state accountability systems (Cuban, 2012). While policy makers believe these changes will also lead to pedagogical changes, this occurs rarely (Cuban, 2012). Therefore, many aspects of the current classroom learning environments are reminiscent of those experienced by past generations of students (Christensen et al., 2011; Christensen et al., 2013; Cuban, 2012).

Many advocates who focus on leveraging the technology available to students and teachers contend technology is an essential element in forcing the major pedagogical shifts needed to produce improved teaching and learning (Christensen et al., 2011; Christensen et al., 2013; Cuban, 2012; Horn, 2010; Horn & Staker, 2012). Disruptive innovation theory explains how an innovation transforms an existing market or sector by introducing a new product or service that eventually redefines the industry (Christensen et al., 2013). According to Christensen et al. (2011), there are two basic types of innovation. Each type follows a different trajectory and leads to different results. The researchers describe these two types of innovation in the following passage:

> Sustaining innovations help leading, or incumbent, organizations make better products or services that can often be sold for better profits to their best customers. They serve existing customers according to the original definition of performance—that is, according to the way the market has historically defined what's good. Disruptive innovations, in contrast, do not try to bring better products to existing customers in established markets. Instead, they offer a new definition of what's good. Over time, they improve enough to intersect with the needs of more demanding customers, thereby transforming a sector. (p. 3-4)

According to Christensen et al. (2013) schools struggle to improve due to sustained innovation. Though sustaining innovations are needed in order for organizations to grow and remain productive with changes that occur over time, significant change must occur when the demands are significantly different and the mode of operation is not producing required results. While changes made over the previous century led to increased student access to education and the opportunities education brings, nonetheless many students continue to be unsuccessful in the current educational environment. In fact, "evidence from many sources shows that the least effective mode for mathematics learning is the one that prevails in most American classrooms: lecturing and listening. Despite daily homework, for most students and most teachers mathematics continues to be primarily a passive activity: teachers prescribe; students transcribe. Students simply do not retain for long what they learn by imitation from lectures, worksheets, or routine homework" (National Research Council, 1989, p. 57). One possible disruptive innovation or transformation that could occur is through the expanded use of technology.

Expanded Use of Technology as a Disruptive Educational Innovation

Though public education has a long and rich history, the use of technology in education spans only the last few decades. The Office of Technology Assessment (OTA) was created by the *Technology Assessment Act of 1972* (2 U.S.C. §471 - Pub. L. 92–484, §2, Oct. 13, 1972, 86 Stat. 797). The first OTA report was submitted to Congress on March 15, 1973. The 1988 OTA report noted while regular computer use at that time was not extensive; most schools had some type of computer availability ("Elementary and Secondary," 1988). At that time, computers had not yet become an integral part of the teaching and learning process.

In 1983, Kulik, Bangert, and Williams observed "programs for computer-based instruction (CBI) have come a long way in the last two decades" (p. 19). Over 30 years ago, Kulik et al. (1983) reported CBI would significantly alter the educational system and lead to increased engagement and improved student achievement. Student and teacher access to and use of the type of technology discussed by Kulik, et al. has increased over time. In 1983, approximately one computer was available for every 125 students in K-12 public schools (Picciano, Seaman, & Allen, 2010). Over the next two decades, more computers became available to schools. For example, by 2004 one computer was available for every four students (Picciano et al., 2010; Skinner, 2002). This ratio held fairly steady over the next few years. The percentage of public schools having Internet access grew from 35% in 1994 to 100% in 2001 (Spencer & Rogers, 2005). According to Skinner (2002), the number of students per Internet-connected computer was 6.8 in 2001 (p. 53). In the United States instructional technology expenditures increased from 2.1 billion in 1992 to 5.8 billion in 2004; with 72% of schools planning to purchase learning-content software and 38% of school districts planning to purchase instructional management systems and purchase assessment software (Quality Education Data, 2004). In addition by 2001, 14 states had established virtual high schools, with the first program coming into existence in 1994 (Clark, 2001). The Illinois Virtual High School (IVHS) was created in 2001 (Clark, 2001). The National Center for Education conducted a survey on behalf of the U.S. Department of Education in public schools during the winter and spring of 2009 and found 97% of teachers had at least one computer in their classroom every day and the ration of secondary students was 5.2 for every 1 computer (Gray, Thomas, & Lewis, 2010). However, it was also determined through the survey the ratio of secondary students in the classroom to computers in the classroom or that could be brought in to the classroom was 1.6 students to every computer (Gray et al., 2010).

With increased availability of computers, remote learning through a virtual environment became an option for many schools and students. According to the National Center for Education Statistics (2013), the percent of school districts across the nation enrolling students in distance education grew from 36% during the 2002-2003 school year to 55% during the 2009-2010 school year; with total student distance learning enrollments growing from a little over 200,000 to over 1.3 million during the same time period. Spencer and Rogers (2006) stated:

> Technology itself has evolved and developed over time as it has broadened its reach and contributed to a multitude of changes in society. Positive and negative, technology has altered our lives. Today, with its infusions into education, particularly at the secondary school level, technology poses both promise and a challenge for educators. Some knowledgeable experts predict most secondary students will receive all or part of their education from Internet-connected computers. (p. 91)

Many schools have begun taking advantage of online distance education through virtual courses. According to Gokool-Ramdoo (2009), "Online distance education refers to a type of educational transaction carried out on an electronic platform that favors student-student, student-content, and student-tutor interactions and carries all resources that support the learner's educational itinerary" (p. 5). In addition, virtual courses may be a viable option for students who would benefit from a course not offered at their local school due to either scheduling constraints or a lack of staff with the expertise or credentials in the needed curricular area. Many students in rural and urban schools have benefitted from the opportunities virtual courses provide (Blaylock & Newman, 2005).

Categorizations of Educational Technology

Though computer-based instruction has become more prevalent there are differences among the available technologies. Nonetheless all computer-based instruction programs are generically labeled as educational technology. Cheung and Slavin's (2013) definition of educational technology is the definition used in the current study. This definition states "educational technology" refers to a "variety of technology-based programs or applications that help deliver learning materials and support the learning process in K-12 classrooms to improve academic learning goals" (p. 90). This definition does not include the learning of technology itself. In addition to defining educational technology, there are also categorizations of the existing types of educational technologies.

Cuban and Kirkpatrick (1998) classified educational technology into three categories: computer assisted instruction (CAI), computer managed instruction (CMI), and computer-enhanced instruction (CEI) (1998, p. 30). CAI includes use of software programs that generally include tutorials or drill and practice. CMI programs may also include tutorial and drill and practice, but also provide diagnostic applications and guidance for learning specific to the student. CEI is the use of technology applications or software where the teacher is an integral part of the instructional process. CAI and CMI can be aspects of CEI in those instances where a teacher plans and implements the use of the CAI and CMI applications. The current study examines the use of CEI with CMI through the Renaissance Learning System being included aspect of instruction.

Blended Learning as a Disruptive Innovation

With the influx of technology and ever-increasing availability of educational programs and applications, many schools have implemented a 1:1 learning environment in which every student has a computing device (Grundmeyer, 2013). As a result of this expanded technology access, a new model of virtual learning has also become a possibility within school classrooms. This type of learning structure, referred to as blended learning, is a hybrid model combining the traditional learning environment with online learning opportunities from either a remote location outside of school or through the use of school-based computer instruction (Cavalluzzo et al., 2012; Rose & Rice, 2015). This hybrid format allows teachers to work with individual or groups of students while other students use technology to interact with content and apply knowledge and skill. In this structure, the teacher remains an integral part of the instructional process. Though there has not been extensive research in the area of blended learning, available studies were reviewed to learn about CEI and its impact on student achievement.

To date, many of these studies have utilized effect size as a reporting mechanism. The utilization of effect size allows researchers to report and interpret the effectiveness of an intervention and is usually associated with meta-analysis (Cohen, 1988). Effect size within a meta-analysis is the standardized difference between the experimental group and the control group divided by the standard deviation. Cohen (1988) defined effect sizes as small (d=.2), medium (d=.5), and large (d=.8) with the following disclaimer, "there is a certain risk in inherent in offering conventional operation definitions for those terms for use in power analysis in as diverse a field of inquiry as behavioral science" (p. 25). Effect sizes are positive when the experimental group outperforms the control group and negative when the control group outperforms the experimental group. Murphy et al. (2002) noted a limitation for meta-analysis in the area of effectiveness of specific educational software was the "failure of studies to report basic information on effect size and implementation" (p. 3).

The U.S. Department of Education (2010) conducted a meta-analysis research study of online learning. The initial search sought studies published between 1996 and 2006. However, no experimental or quasi-experimental studies for K-12 comparing online learning to traditional face-to-face learning structures were found. As a result, the search was extended to include studies through 2008. Forty-five studies provided sufficient information to compute independent effect sizes that could be utilized in the meta-analysis, with only four of the studies involving K-12 learners. The meta-analysis found classes with online learning (whether taught completely online or via a blended delivery model) produced stronger student learning outcomes than classes with only face-to-face instruction with an effect size of +0.20. Learning involving a blend of online and face-to-face instruction had a mean effect size of +0.35. In addition, the strongest evidence of effectiveness was found when learning experiences were paired with pedagogical practices designed to increase student self-reflection and learning environments allowing for individualized learning. The study also listed and defined the following types of learning experiences occurring through the integration of technology into the teaching and learning process:

- Expository Instruction – Digital devices transmit knowledge.
- Active Learning – The learner builds knowledge through inquiry-based manipulation of digital artifacts such as online drills, simulations, games, or micro worlds.
- Interactive Learning – The learner builds knowledge through inquiry-based collaborative interaction with other learners; teachers become co-learners and act as facilitators (p. 3-4).

There are many online or blended learning advocates (Horn & Staker, 2012; Christensen et al., 2013; Rose & Rice, 2015). For example, Horn and Staker (2012) recommended virtual schooling because they believed there was a need to disrupt the status quo. They also believed online learning environments transformed the educational landscape through disruptive innovation (p. 2). Horn and Staker (2012) acknowledged disruptive innovations such as virtual schooling may not initially seem as effective as the existing system; however, over time, the disruptive innovations improved through implementation and supplanted the old methods (p. 2). Therefore, proponents urge the use of teacher training and professional development to support implementation of virtual schooling.

According to Chatti, Jarke and Specht's (2010) 3P learning model, there are five critical factors related directly to technology-enhanced learning (TEL) success. These factors include learning that is personal and self-directed, social, open, emergent, and driven by knowledge-pull (2010). Chatti et al. (2010) describes emergent learning as being non-linear and occurring through various complex interactions among individuals and technology; and knowledge-pull learning environments as settings in which the learning is self-directed instead of the knowledge flowing predominantly through the teacher (p. 75). Chatti, Jarke, and Specht (2010) proposed moving away from "the one-size-fits-all, centralized, top-down, and knowledge-push models of traditional learning model" (p.75). Knowledge-push learning structures are characterized by teacher-centric approaches, where the instructor is the major source or possibly only source of knowledge in the educational setting. In a "knowledge-pull" educational environment there are multiple modes for students to access information, i.e., students determine how they access information; therefore, making the learning environment more personalized to the individual learner. Implementation of a virtual learning model within districts and schools that shifts towards a more personalized, learner-centric environment and is grounded in the Theory of Disruptive Innovation may cause instruction to be transformed from the status quo (Horn, 2010).

Increased Personalization and the Station-Rotation Model for Blended Learning

People learn in different ways. Therefore, personalization of the learning process is important as public educators strive to change the trajectory of student achievement (Christensen et al., 2011). According to Chatti et al. (2010), "It is widely recognized that effective and efficient learning needs to be individualized-personalized, and learner-controlled" (p. 76). McLoughlin and Lee (2008) noted the need to implement more learner-centric teaching and learning models (p. 10). Within a blended learning model, where at least part of the course is delivered online or through a computer-based system, students have a measure of control over the time and pace of their learning (Walne, 2012; Fuel Education, 2014). Horn and Staker (2012) categorized blended learning into four different models based on classroom observations and teacher interviews. The four models included rotation, flex, self-blend, and enriched-virtual; with station-rotation, lab-rotation, flipped-classroom, and individual-rotation as sub-categories within the rotation model. All models within the rotation model include a specific delineation of when and where the technology is utilized. Within the flipped-classroom model, technology is leveraged outside of the classroom usually in the form of content delivery and practice in an effort to maximize class time to apply the learned content while the teacher is physically present. The station-rotation, lab-rotation, and individual-rotation include technology used within regularly scheduled class time; however, as indicated by the names of the models, students move either in groups or individually to the technology. All models included the use of technology as a core instructional component. In the station-rotation model students and teachers meet during a scheduled class period during the school day. However, the teacher utilizes technology as a station within the classroom. The station-rotation model enables teachers to differentiate for student needs within the classroom without students being pulled out to a lab or another classroom, thus allowing teachers to work with smaller groups of students within the same classroom. Successful implementation of this model requires effective classroom management and the availability of technology that students can easily and individually navigate (Walne, 2012).

The station-rotation model for blended learning allows the teacher to incorporate the use of either CAI or CMI applications, such as Renaissance Learning, as a station or component within the classroom, thereby enabling students to work at their individual level while the teacher is working with individual or groups of students. This model permits the teacher to decrease the student to teacher ratio during direct instruction. Therefore, increased instructional personalization occurs as students work within the Renaissance system as well as during periods of direct instruction. Renaissance Learning utilizes a three-tiered learning pyramid (Renaissance Learning, 2011, p. 2). Level 1 of the pyramid includes daily practice monitoring; Level 2 includes interim assessments used for screening, benchmarking, and progress monitoring; and Level 3 includes summative assessments, or assessments of learning. According to the Renaissance Learning literature, daily practice monitoring can encompass a large variety of learning activities (Renaissance Learning, 2011, p.2). Through daily practice monitoring, students should receive feedback on their progression as teachers gather data to inform future planning and instruction.

Research on Implemented Mathematics Technologies in the Classroom

To date, the effectiveness of blended learning environments, including hybrid structures in mathematics courses, has not been thoroughly researched (Cavalluzzo et al., 2012). While research has been conducted in the area of CAI and mathematics achievement, this research has yielded mixed results (Kulik & Kulik, 1991; Cuban & Kirkpatrick, 1998; Kulik, 2002; Murphy et al., 2002; Dynarski et al., 2007; O'Dwyer, Carey & Kleiman, 2007; Campuzano, Dynarski, Agodini & Rall, 2009; Cheung & Slavin, 2013; Hadjerrouit, 2011). For example, some meta-research studies found a decline in the effect of CAI on student achievement (Kulik & Kulik, 1991; Cheung & Slavin, 2013). It should also be noted studies on the effectiveness of educational technology are generally of limited value unless they include a high level of specificity regarding content area, age of students, and specific software utilized (Cuban & Kirkpatrick, 1998).

Moore (1998) investigated the influences of CAI and teacher personality on the achievement of seventh and eighth grade remedial math students. Students in this study included both general education and special education students. The specific computerized mathematics program utilized with students receiving treatment was the Milliken Math Sequence. This program individualized the instruction for each student and included immediate feedback to both the student and the teacher. Interviews were conducted with teachers, their colleagues, and the principal to determine whether the teacher had a positive or negative attitude toward working with remedial students. There were four groups within this study; positive CAI, negative CAI, positive direct instruction, and negative direct instruction. The "positive" and "negative" labels within this study denoted the teacher's affective influence with respect to attitudes, expectations, and interpersonal interactions. These influences were determined by using interviews with the teachers in the study as well as interviews with building principals and teachers who were in close proximity to teachers participating in the study. All students in the study were given a pre-test in September and post-test in May. An Analysis of Covariance (ANCOVA) was used to assess the differences between the pre- and post-test scores (p. 41).

The study found higher achievement for students with positive teachers in both groups. The group showing the highest post-test growth was the CAI group with positive teachers. However, students receiving CAI with negative teachers also showed slightly more growth than students receiving direct instruction with negative teachers. Moore (1998) concluded, "Although

CAI is undoubtedly helpful for increasing student achievement, it is doubtful that computers can overcome the teacher's affect and influence" (p. 44).

In 1999, in response to poor student performance in a Cape Cod high school, officials launched a three-tiered program that included curriculum realignment, professional development, and planning focused on student mastery of curricular objectives (Hannafin & Foshay, 2008). In 2000, the school also implemented the Plato Learning System as a computer-based course for tenth grade students who were in danger of failing as was predicted based upon their eighth grade scores on the mathematics portion of the state's end-of-year exam. The course goals were to:

- Match course curriculum to target objectives covered in the end-of-course assessment and the state standards,
- Provide individual remediation for academically at-risk students to pass the end-of-course assessment,
- Provide assessment and tracking for individual students, and
- Improve students' learning habits.

The measurement of the effect of CBI focused on the 2001 Massachusetts Comprehensive Assessment System (MCAS), data from the CBI program, and the perceptual data from the CBI instructor (p. 152). A repeated Analysis of Variance (ANOVA) measure was used to compare the 87 students assigned to the CBI course based on "failing or marginal 8th grade MCAS scores" and the 39 students in the control group (p. 153).

Hannafin and Foshay (2008) found the CBI group outperformed the non-CBI group as measured by the state's end-of-course exam, with passing rates for the course also increasing overall. However, the study also found though lower performing students outperformed comparative students within the state, higher achieving students in the research group were outperformed by their state student achievement group. Specifically, 84% of students in the research group passed the end-of-course exam as compared to 75% of the state student achievement group (p. 155). Hannafin and Foshay (2008) also found a significant positive correlation between the end-of-course achievement data and student mastery of modules utilizing the CBI program. It is also noted, overall the state saw an increase in student achievement during the same time period and CBI was not the only initiative implemented in an effort to improve state assessment scores.

Two studies were conducted by the National Center for Education Evaluation and Regional Assistance to examine the effectiveness of additional mathematics software products (Campuzano et al., 2009; Dynarski et al., 2007). Dynarski et al. (2007) focused on three technology software products designed for algebra instruction; Cognitive Tutor Algebra, Plato Algebra, and Larson Algebra (p. 63). The researchers utilized geographical diversity, high poverty rates, and number of volunteer teachers as criteria for participation in the study. This resulted in 10 school districts, 23 schools, 71 teachers, and 1,404 students participating in the algebra research group (p. 8). The researchers utilized an experimental design employing random assignment of teachers within each school to the treatment or the control group. Only teachers in the treatment group were asked to implement the selected technology. Four percent of the teachers in the treatment group and ten percent of the teachers in the control group reported using additional technology software during instruction (p. 64). Teachers in the treatment group could decide to stop using the technology product during the study. The study utilized the Educational Testing Services' (ETS) End-of-Course Algebra Assessment (1997) to measure algebra achievement with a pre-test given to students in both groups at the beginning of the 2004-2005 school year and a post-test administered at the end of that school year (p. 13). If available, local assessment data was also reviewed. The study utilized three classroom observations of each teacher in each group and collected additional information from teacher surveys, interviews, student records, and records from the technology software. The following implementation findings were noted:

- Nearly all teachers received training and believed the training prepared them to use the products;
- Technical difficulties using the products were generally minor; and
- When products were being used, students were more likely to engage in individual practice and teachers were more likely to facilitate student learning rather than lecture (p. 73).

The researchers found the differences in tests scores were not statistically significant between the treatment and control groups.

Campuzano et al. (2009) continued the Dynarksi et al. (2007) study by collecting data during the 2005-2006 school year with a new cohort group of students to determine if additional teacher experience with the products had an effect on student achievement. Campuzano et al. (2009) focused on only two math products for Algebra 1, Cognitive Tutor Algebra 1 (Carnegie Learning 2008) and Larson Algebra 1 (Houghton-Mifflin 2008). Twenty-four teachers participated in both the first and second year of the study, and 1,051 students (517 during year 1 and 534 in year 2), with a majority of the students in high school (p. 32). Researchers found a statistically significant increased product effect difference on test scores in the second year, with the effect of software products on Algebra 1 tests equivalent to a student going from the 50th percentile to the 56th percentile, while the first year study yielded a statistically insignificant difference equivalent to a student moving from the 50th percentile to the 49th percentile.

Tienken and Wilson (2007) studied the impact of CAI on seventh grade student achievement in New Jersey schools. A quantitative, quasi-experimental design, using ANOVA was utilized in this study. The seventh grade students within the treatment group utilized mathematics websites focused on basic mathematical skills and the use of presentation software to share reports with their peers. Student achievement on the mathematics portions of the TerraNova Full Battery standardized test was compared to the achievement of students who did not receive the treatment. A two-way ANOVA was conducted first to control for pre-test differences as well as to examine a possible interaction effect due to socioeconomic status (SES). After it was determined there was no interaction between SES and test scores, a one-way ANOVA was utilized. The study found a positive relationship existed between the TerraNova test scores and low-socioeconomic and high socioeconomic students utilizing the CAI drill and practice exercises on the mathematic websites along with the presentations in which the students explained their learning. However, the effect size was small according to the Cohen's *d* calculation (p. 187).

Though Tienken and Wilson's (2007) results were statistically significant and positive with respect to the relationship between student achievement and CAI, subsequently the researchers found contrasting results (Tienken and Maher, 2008). Tienken and Maher (2008) analyzed results from a quantitative, quasi-experimental study, using ANOVA to determine what, if any, relationship existed between CAI and the academic achievement of New Jersey eighth grade students. The treatment group received CAI and their achievement was compared to a control group that received traditional math instruction. The CAI used in this study focused on drill and practice. The study compared the following groups of students: “students who scored in the same quartile of the TerraNova grade 7 mathematics assessment, students who participated in similar basic skill instruction (BSI) mathematics and/or remediation service programs, students who did not participate in BSI mathematics and/or reading remediation service programs, students who were in the same ethnic group, and students who participated in the same level of the school’s free or reduced-price lunch program” (p. 5). Students in both the control group and treatment groups took the same pre-test and post-test. Both groups also used the same curriculum and resources. Limitations of this study included the small number of teachers and the high number of low-socioeconomic students (p. 5). The post-test utilized in this study was the mathematics section of the New Jersey Grade Eight Proficiency Assessment (GEPA). The researchers found the CAI did not have a statistically significant positive influence on student academic achievement, with two categories of students in the treatment group performing statistically significantly lower than the control group (p. 11).

Slavin, Lake, and Groff (2009) examined effective middle and high school mathematics programs that utilized CAI. Thirty-eight CAI studies were reviewed in total, with 19 studies including high school programs. The researchers found an overall median effect size of +0.10. Nine of the studies were categorized as randomized-experimental or randomized quasi-experimental and also showed an effect size of +0.10 (p. 858).

Cheung and Slavin (2013) noted a need for high quality evaluation for the ever-increasing software applications being utilized in classrooms (p. 102). Cheung and Slavin (2013) conducted a meta-research analysis of 74 studies. This analysis included 45 elementary studies, and 29 secondary studies, with a total sample size of 56,886 K-12 students. They found educational technology produced a small positive effect (+0.16) on mathematics achievement. Cheung and Slavin (2013) identified various problems with previous reviews of the effects of educational technology on mathematics achievement that found an overall study-weighted effect size of +0.31 of the reviews in question, though the effect size ranged from +0.10 to +0.62 (p. 90).

Only two of these studies focused on high school students. Nine of the studies focused on elementary students, three focused on elementary and secondary, and seven focused on students from elementary to college level. One problem was many of the studies did not include a control group for comparison, making it difficult to determine if the effect was caused by the program or simply by normal gains. A second problem was the brevity of some of the studies, i.e., "short-duration studies tend to produce larger effects than long-duration studies" (Cheung and Slavin, 2013, p. 92). A third problem was some studies did not establish initial equivalence, making it impossible to know whether the control group and treatment group were comparable at the beginning of the study. A fourth problem was the measureable outcomes in some studies were appropriate only to the treatment group. A final concern shared with previous reviews regarded the findings from Dynarski et al. (2007) and Campuzano et al. (2009) where the effects of CAI were not consistent with previous studies of the effects of CAI and student achievement.

Over 70% of the studies reviewed by Cheung and Slavin (2013) were categorized as supplemental CAI technology, and studies within this category demonstrated an effect size of +0.19. Cheung and Slavin (2013) also reviewed the studies for trends in effect size over time, reporting the "mean effect sizes for studies in the 80s, 90s, and after 2000 were +0.23, +0.15, and +0.12 respectively" (p. 97). In regard to grade level, Cheung and Slavin (2013) found a higher effect size for elementary (+0.17) than for secondary students (+0.14) (p. 97), though Cohen

(1988) would describe both as small effect sizes. According to Cheung and Slavin (2013), "educational technology is making a modest difference in learning of mathematics" (p. 102).

The previously discussed studies focused primarily on CAI and student achievement. Blended learning is a relatively new model in education. As a result, there is little research on CAI's impact on student achievement, and only one research study researched the impact of blended learning upon mathematics achievement within a high school setting. Cavalluzzo et al. (2012) conducted a study analyzing the effectiveness of the Kentucky Virtual Schools' hybrid program for Algebra 1, in which 25 schools (13 treatment and 12 control) in 2007-2008 and 22 schools (11 treatment and 11 control) in 2008-2009 from a volunteer sample of 47 schools participated (p. 10). The study was limited to schools with a maximum of 60% of students proficient in mathematics as measured by either the Comprehensive Test of Basic Skills, version 5 or the Kentucky Core Content Test (p. 12). All schools in the study volunteered for participation, with schools randomly assigned to the treatment or control groups. All Algebra 1 teachers and students in a school were assigned to the school's treatment group. This group included "professional development and materials for all participating teachers and follow-up support throughout the year" (p. 13). The researchers found no statistically significant effect on student achievement either as a whole or by student gender, student cohort, or school rural status (p. xii).

The Kentucky Virtual Schools' hybrid program was a blended intervention program that combined a traditional face-to-face educational setting with an online instructional component in an effort to increase student achievement. The online component was the National Repository of Online Courses, a customizable Internet-based resource selected by the Kentucky Virtual

Schools and Kentucky Department of Education. Students were expected to access the online course resource at least twice per week (Cavalluzzo et al., 2012, p. 2).

The goal of the blended course was to increase student achievement in classes taught by "inexperienced or less successful" teachers, thereby increasing overall instruction of Algebra 1 and better preparing students for subsequent mathematics courses (Cavalluzzo et al., 2012, p. 2). Cavalluzzo et al. utilized a randomized controlled trial with an intent-to-treat (ITT) analysis at the school level to study the effects of the hybrid model that included teachers being provided both ongoing professional development on how to effectively utilize the online resources in a hybrid setting and research-based instructional classroom practices. Teacher professional development began during the summer prior to implementation of the blended course and continued during the school year. The professional development included both face-to-face and remote educational structures. Additionally, site visits and subsequent coaching sessions with instructional specialists were also utilized as part of the on-going teacher professional development. The summer professional development also utilized the Spotlight on Algebra 1 program developed by the Southern Regional Education Board (SREB) (Cavalluzzo et al., 2012, p. 48). The study utilized student scores on the pre-algebra/algebra portion of the American College Testing (ACT) PLAN assessment administered during the fall of grade 10 to measure the impact of the hybrid intervention program in Algebra 1 (Cavalluzzo et al., 2012).

The treatment group consisted of 6,908 students, with 61.4 percent of the students attending rural schools (Cavalluzzo et al., 2012, p. xi). The researchers utilized data from the PLAN test taken during the school year following the intervention. Hierarchical linear models were used to assess differences in outcomes between the treatment and control schools (p. xii). Teacher surveys and classroom observations were utilized to collect teacher perceptions and implementation data. The Wilcoxon-Mann-Whitney test was used to determine statistical significance of teacher attitudes and observations between the treatment and control groups (p. 60-62).

Though the study found no statistically significant effect on student achievement, the following limitations of the findings were noted:

- Four of the twenty-four treatment schools did not participate in the intervention;
- Twenty of the sixty-three teachers did not participate in any component of the intervention;
- Less than 50% of the treatment sample had high or moderate teacher attendance in the professional development sessions;
- Nineteen percent of teachers were rated as having low engagement during the summer professional development;
- Thirty percent of teachers were rated as having low engagement during the school year professional development; and
- Sixty-five of treatment students had ratings of no or low use of the Kentucky Virtual Schools' online Algebra 1 materials during the intervention period (p. 75-76).

As previously acknowledged, to date, there is little research on the impact of the use of CAI or CMI through a blended learning structure upon student mathematics achievement. Cavalluzzo et al. (2012) was the only research study of this type found, and the study's findings indicated no statistically significant effect on student achievement.

Importance of Professional Development in Successful Technology Integration

Before transformation can occur, school officials must understand the obstacles that may inhibit instructional improvement through technology integration. Hew and Brush (2006) identified 123 barriers to technology integration and grouped these barriers into six categories: resources (40%), institution (14%), subject culture (2%), attitudes/beliefs (13%), knowledge/skills (23%), and assessment (5%). According to this meta-analysis the aggregate of the categories (resources, knowledge/skill, and institution) equated to 77% of the total.

According to Hew and Brush (2006), 40% of the identified barriers were categorized as resources. Within the resource category, availability and access to technology were imperative. However, the lack of time for teacher training as well as time dedicated to teacher planning for technology integration were also cited as obstacles (Hew & Brush, 2006). The category with the second highest percentage was associated with knowledge/skill barriers, specifically identifying the lack of knowledge and skill associated with specific technology as well as a lack of skill in regards to classroom management and pedagogy associated with technology (p. 227). Finally, the category associated with institutional barriers represented 14% of barriers identified within the studies. Specifically, institutional barriers included leadership, structure, and planning (p. 228). In response to the barriers identified through their meta-analysis, Hew and Brush (2006) proposed the following strategies to overcome these barriers: "having a shared vision and technology integration plan, overcoming the scarcity of resources, changing attitudes and beliefs, conducting professional development, and reconsidering assessments" (p. 232).

Professional development for teachers is key to successful classroom technology integration. Hokanson and Hooper (2004) voiced concern regarding the use of computers not being integrated within the curriculum because historically computers have been used as a transmission device instead of a learning device; or the difference in “learning from” technology and “learning with” technology (p. 247). Effective professional development in the area of technology integration must focus on content, be relevant, and allow for authentic practice with the desired technology to be integrated (Hew & Brush, 2006, p. 238).

Research Questions and Hypotheses

This study seeks to determine if there is a relationship between the use of CEI, specifically the Renaissance Learning System, through the blended learning station rotation model, and student achievement in mathematics. The following section reintroduces the specific research questions identified in Chapter One that are the focus of this study and provides highlights from the literature review to support the accompanying hypotheses. Both the Renaissance Learning System and the Educational Planning and Assessment System (MATH EXPLORE) are explained more thoroughly in Chapter Three.

Research Question 1: Are there differences in the amount of student mathematics achievement growth between the control student group and the student treatment group receiving computer-enhanced instruction (CEI) as measured by the Educational Planning and Assessment (MATH EXPLORE) of ninth-grade Algebra 1 students?

Hypothesis 1: The use of CEI with ninth-grade Algebra 1 students positively impacts student math achievement as measured by the MATH EXPLORE mathematics assessment.

Research Question 2: Are there differences in the amount of student mathematics achievement growth between the control student group and the student treatment group receiving computer-enhanced instruction (CEI) as measured by the Educational Planning and Assessment (MATH EXPLORE) of ninth-grade Honors Algebra 1 students?

Hypothesis 2: The use of CEI with ninth-grade Honors Algebra 1 students will positively impact mathematics achievement as measured by the MATH EXPLORE mathematics assessment.

Though there has not been extensive previous research in the area of blended learning, studies have found small effect sizes for online or blended learning environment in comparison to traditional learning environments (U.S. Department of Education, 2010). In addition to the U.S Department of Education's meta-analysis (2010), other studies also found a small to moderate positive impact of computer based instruction (CBI), computer-enhanced instruction (CEI), and computer assisted instruction (CAI) (Hannafin & Foshay, 2008; Tienken & Wilson, 2007; Slavin et al., 2009; Cheung & Slavin, 2013).

Research Question 3: Are there differences in the amount of student mathematics achievement growth between the control student group and the student treatment group receiving computer-enhanced instruction (CEI) as measured by the Educational Planning and Assessment (MATH EXPLORE) of ninth-grade students who enter high school performing below grade level in mathematics?

Hypothesis 3: The use of CEI with ninth-grade Algebra 1 students who enter high school performing below grade level in mathematics positively impacts student mathematics achievement as measured by the MATH EXPLORE mathematics assessment.

In addition to the research cited for Research Questions One and Two, Moore (1998) specifically investigated computer assisted instruction (CAI) and the achievement of seventh and eighth grade remedial mathematics students. The CAI program individualized the instruction for each student and included immediate feedback to both the student and the teacher. The researchers found students in the CAI group had higher post-test growth than students who did not receive treatment.

Research Question 4: Are there differences in the amount of student mathematics achievement growth between Algebra 1 students whose teachers regularly utilize computer-enhanced instruction (CEI) as a pedagogy within their Algebra 1 course and students whose teachers who do not regularly use CEI within their Algebra 1 course as measured by the Educational Planning and Assessment (MATH EXPLORE)?

Hypothesis 4: Algebra students whose teachers regularly utilize CEI as a component within their Algebra course will show more growth on the MATH EXPLORE mathematics assessment.

Between 1995 and 2006 Hew and Brush (2006) analyzed the use of technology integration with 48 studies. The researchers identified 123 barriers to technology integration. These barriers were grouped into six categories; resources (40%), institution (14%), subject culture (2%), attitudes/beliefs (13%), knowledge/skills (23%), and assessment (5%). Within the resource category, availability and access to technology were imperative to successful technology integration. Therefore, an obstacle to technology integration existed for students whose teachers were not directing them to regularly utilize the CEI program

Research Question 5: Are there differences in the amount of student mathematics achievement growth between Algebra 1 students whose teachers self-report a positive perception of computer-enhanced instruction (CEI) and students whose teachers self-report a negative perception of CEI as measured by the Educational Planning and Assessment (MATH EXPLORE)?

Hypothesis 5: Algebra students whose teachers have a positive perception of CEI will show more growth on the MATH EXPLORE mathematics assessment than students whose teachers have a negative perception of CEI.

Between 1995 and 2006 Hew and Brush (2006) analyzed 48 studies focused on the use of technology integration. The researchers identified 123 barriers to technology integration. These barriers were grouped into six categories; resources (40%), institution (14%), subject culture (2%), attitudes/beliefs (13%), knowledge/skills (23%), and assessment (5%). Within the resource category, availability and access to technology were imperative to successful technology integration. Therefore, an obstacle to technology integration existed for students whose teachers had negative attitudes or beliefs.

Research Question 6: Are there differences in the amount of student mathematics achievement growth between Algebra 1 students whose teachers self-report a more student-centric instructional approach and students whose teachers self-report a less teacher-centric instructional approach as measured by the Educational Planning and Assessment (MATH EXPLORE)?
Hypothesis 6: Algebra students whose teachers have a more student-centric instructional approach will show more growth on the MATH EXPLORE mathematics assessment than students whose teachers have a more teacher-centric instructional approach.

According to Chatti et al. (2010), “It is widely recognized that effective and efficient learning needs to be individualized-personalized, and learner-controlled” (p. 76). McLoughlin and Lee (2008) noted the need to implement more learner-centric teaching and learning models (p. 10). Within a blended learning model, where at least part of the course is delivered either online or through a computer-based system, students have a measure of control over the time and pace of their learning (Walne, 2012; Fuel Education, 2014). According to Chatti et al.'s (2010) 3P learning model, there are five critical factors related directly to the success of technology-enhanced learning (TEL). These factors include learning that is personal and self-directed, social, open, emergent, and driven by knowledge-pull (2010). Chatti et al. (2010) described emergent learning as being non-linear and occurring through various complex interactions among individuals and technology; and knowledge-pull learning environments as settings in which the learning is self-directed instead of the knowledge flowing predominantly through the teacher (p. 75). Chatti, Jarke, and Specht (2010) proposed movement away from "the one-size-fits-all, centralized, top-down, and knowledge-push models of traditional learning model" (p.75). Knowledge-push learning structures are characterized by teacher-centric approaches, where the instructor is the major source or possibly only source of knowledge in the educational setting. In a "knowledge-pull" educational environment there are multiple modes for students to access information, i.e., students determine how they access information; therefore, making the learning environment more personalized to the individual learner.

CHAPTER 3

METHODOLOGY

Participants

The current study includes two cohorts of ninth-grade students in a suburban public high school district located southwest of Chicago, Illinois. The study spanned the 2013-2014 and 2014-2015 school years. The first student cohort was the pre-intervention or control group and included students who were enrolled in Algebra 1, Honors Algebra 1, or Algebra 1 Support during the 2013-2014 school year. The second student cohort was the intervention group comprised of students who were enrolled in Algebra 1, Honors Algebra 1, or Algebra 1 Support during the 2014-2015 school year. These students were selected because the Algebra 1 and Honors Algebra 1 curricula were aligned to the Common Core State Standards (CCSS) for the 2013-2014 school year. The same curriculum for both courses was in place for both cohorts during the 2013-2014 and 2014-2015 school years. Licenses for the Renaissance Learning System were purchased for all students in Algebra 1 and Honors Algebra for the 2014-2015 school year, and teachers were trained to use the system.

School District Background

The school district is located within a large city in Illinois situated approximately 45 miles southwest of Chicago, Illinois with a population of 147,433 (U.S. Census Bureau, 2010). The city is a diverse community comprised of 53% White, 28% Hispanic, 16% Black, 2% Asian, and 1.4% of persons representing two or more races. According to the Census Bureau, the city has an estimated 10.8% of the population living below the poverty level compared to the county's rate of 7.2% and is just slightly above the state rate of 10.7%. The U.S. Bureau of Labor Statistics reported the average annual unemployment rate for the county in 2013 was 9.4% compared to the State of Illinois figure of 9.1% and the U.S. figure of 7.45% for 2013 (U.S. Bureau of Labor Statistics, 2013).

The 2013 *No Child Left Behind* (NCLB) Annual Yearly Progress (AYP) Status Report indicated both of the school district's high schools were in the NCLB's Restructuring Implementation stage and Year 10 of Academic Watch Status. According to the Illinois State Board of Education, both high schools were ranked in the bottom 20% of low performing Illinois public high schools. The 2013-2014 Illinois Report Card showed:

- 63.3% of the student population enrolled in the school district received free and reduced lunch,
- High School A (75%) and High School B (52%), both were above the state average of 52%,
- Three percent of the school district's student population was categorized as homeless, and
- According to the 2013 AYP Status Reports, the mobility rate for High School A was 13% and the mobility rate for High School B was 11%.

According to the 2013-2014 Illinois Report Card, 6,204 students were enrolled in the school district's two campuses: High School A (3,081) and High School B (3,123). During the 2013-2014 school year the overall school district student population was comprised of 27.8% White, 24.8% Black, and 43.4% Hispanic. High School A student population included 19.5% White, 23.6% Black, and 53.3% Hispanic, and the High School B student population included

36% White, 25.9% Black, and 33.5% Hispanic. Students with an Individual Education Plan (IEP) (i.e., students who were determined eligible to receive special education services) accounted for 17.3% of the school district's total student population. Each high school campus serves grades 9 through 12.

Mathematics Sequence and Placement

Most incoming ninth-graders, with the exclusion of some special education students, were enrolled in Algebra 1 during their freshmen year. The EXPLORE assessment was administered to students in the fall of their eighth grade year and the results of this test were utilized to enroll students in Algebra 1, Honors Algebra 1, Geometry, or Honors Geometry courses. The mathematics scale score was also used to determine whether a student would be placed in mathematics support in addition to the Algebra 1 course. Any student with a mathematics scale score of 13 or below was automatically placed in a support class. Generally, students who did not have EXPLORE scores were also placed in a mathematics support class. This support class served as a Tier 2 intervention for students, with content and skill gaps remediation being the instructional goal. Students progressed from Algebra 1 to Geometry and thereafter to Algebra 2.

During the summer of 2013, the Algebra 1 and Honors Algebra 1 curricula were rewritten to align with the Mathematics CCSS. The school district adopted an integrated mathematical approach to the core sequence based upon the Illinois State Board of Education's (ISBE) guidance for integrated mathematics. This curriculum was implemented during the 2013-2014 school year. The curriculum was refined during the summer of 2014 and common assessments aligned with the curriculum were developed. This refinement included only minor changes to the curriculum. This refined curriculum and associated assessments were implemented during the 2014-2015 school year.

Intervention

As previously noted, the Accelerated Math system can be used along with the STAR Math system. In this case, the screening and benchmarking data help inform student placement in the appropriate library. The STAR system also provides information regarding the effectiveness of the curriculum by providing benchmarking and progress monitoring data.

The school district first purchased licenses for both STAR and Accelerated Math for the 2013-2014 school year. During the summer preceding the 2013-2014 school year, all algebra support and Algebra 1 teachers were trained on both the use of the STAR Math and the Accelerated Math systems. All Algebra 1 teachers were expected to utilize the STAR Math system to assess their students using the benchmarking assessments. Testing windows were determined and communicated in advance. Mathematics support teachers were asked to use the Accelerated Math system with their students on a regular basis as both a diagnostic and progress monitoring tool. Algebra 1 teachers also had access to the Accelerated Math system for their students, but were not given specific parameters for the use of the system.

During the summer of 2014, teachers who had regularly utilized the system during the previous year were provided salary stipends to develop custom libraries within the system that aligned with the units within the school district’s integrated Algebra 1 course. These teachers planned professional development for Algebra 1 teachers. This professional development was implemented during an institute session to ensure all Algebra 1 teachers had access to the training. During this training, the Curriculum Director for Mathematics communicated the District 204’s vision for the use of the program as well as the associated expectations.

The vision for the use of STAR Math was to continue the use of interim assessments to benchmark student achievement three times per year in Algebra 1 and Honors Algebra 1 and expand the use of the interim assessments to geometry and honors geometry.

The vision for the use of Accelerated Math in algebra and mathematics support classes was for the system to be used as the primary intervention tool within both algebra and geometry support with the goal of remediating skill deficits that would allow students to be successful in their associated mathematics course.

This vision for the use of Accelerated Math in Algebra 1 was for the tool to be utilized in a blended station rotation model on a regular basis, allowing teachers to more effectively differentiate instruction based upon student needs. Teachers were given the option of either utilizing the libraries created the previous summer by school district teachers or creating their own libraries to utilize with their students.

The goal was for teachers to utilize the program as a technology enhancement, thereby providing teachers complete ownership of their planning and associated lessons. Two benefits of using the system were homogenous grouping of students based on student skill level in addition to the ability to provide immediate feedback to students while the teacher was working with another group of students. This provided each teacher with a tool to decrease the ratio of teacher to students during direct instruction. Teachers were also directed to plan and implement project based learning activities designed to complement the libraries/units students were working on within the Accelerated Math system.

Renaissance Learning Tool

The specific CMI program researched in the current study was the Renaissance Learning System that included the Accelerated Math program. Various intervention reports can be found through the U.S. Department of Education's Institute of Educational Sciences. Specifically, the What Works Clearinghouse (WWC) reviews various studies according to their review protocol evidence standards. Specific math intervention reports are available for Carnegie Learning Curricula, Cognitive Tutor Software, and I Can Learn Mathematics Curriculum. However, according to the WWC report for Accelerated Math no studies were conducted that met the WWC's evidence standards, though three studies met evidence standards with reservations. These studies all included students in grades 6 through 8, and the WWC stated the evidence to be medium to large for mathematics achievement. The WWC was not able to report on the effectiveness of the Accelerated Math program for high school students (U.S. Department of Education, 2011). STAR Math and Accelerated Math are two discrete components of the Renaissance Learning System that can be used either in isolation or together.

STAR Math is a web-based software tool published by Renaissance Learning that allows teachers and schools to benchmark and monitor student progress in grades 1-12 (U.S. Department of Education, 2011). According to the Renaissance Learning literature, daily practice monitoring can encompass a large variety of learning activities, including the use of Accelerated Math (Renaissance Learning, 2011, p.2). Through daily practice monitoring, students receive feedback on their progression as teachers gather data to inform future planning and instruction.

The assessments housed within STAR Math are all computer-adaptive tests (CATS). This type of assessment utilizes student data as the test is being taken and simultaneously adjusts to each student's appropriate skill level (Renaissance, 2011, p. 5). This benefits both students and teachers because this type of computer adaptive intelligence causes less frustration or boredom for students and also results in less instructional time being used for assessments.

STAR Math uses a growth model determined as a result of using data gathered from over 350,000 students (Renaissance, 2011, p. 10). The system groups students into ten different percentile groups, or deciles. According to the literature, "this level of specificity enables educators to compare a student's growth rate to students with scores in the same decile, making the Goal-Setting Wizard growth predictions more accurate than a 'one-size-fits-all' growth rate" (2011, p. 10). In turn, the Goal-Setting Wizard provides teachers with recommended goals for each student. A teacher may choose either a "Moderate" or an "Ambitious" goal for a student, with a moderate goal representing a goal in which 50% of students in the same percentile group would attain and an ambitious goal representing a goal in which 25% of students in the same percentile group would attain (p. 10). The program does not remove the teacher's professional judgment. However, it does provide additional information based on a large data-set that may be used to inform student growth targets.

Accelerated Math is also a web-based software tool that can be utilized either with STAR Math or separate from STAR Math. The Accelerated Math system utilizes "libraries" aligned with both state and national standards, including the CCSS. Teachers and schools have the option of creating their own libraries that align with their specific curriculum. Students are assigned to the appropriate library and the system creates individualized assignments for each student based on their library placement. This allows teachers to more effectively differentiate for individual student readiness levels (U.S. Department of Education, 2011). Progression through these assignments along with the aligned assessments within the system allows students and teachers to receive immediate feedback.

Instrumentation

EXPLORE Assessment

The current study sought to determine if a relationship exists between the use of computer-enhanced instruction (CEI), specifically the Renaissance Learning System through the blended learning lab rotation model, and student mathematics achievement. The use of CEI was the independent variable in this study. The dependent variable was the student growth between EXPLORE 8 and EXPLORE 9 on the mathematics portion of the assessments.

ACT's Educational Planning and Assessment System (EPAS-MATH EXPLORE) is a longitudinal assessment system that allows teachers and school administrators to track student growth and achievement (Allen et al., 2009). The assessments are given to students in grades 8 through 12, with the EXPLORE assessment usually being given in grade 8 or 9, the PLAN assessment usually given in grade 10, and the ACT given in grade 11 or 12. There are four distinct subtests comprising each assessment including reading, English, mathematics, and science.

According to ACT, the EXPLORE tests are given in an effort to prepare students for high school studies, with many schools utilizing the data to inform student placement. The PLAN test is utilized for planning and preparation for college and the workplace, and the ACT is the capstone test of the series, utilized for college entrance and beyond (ACT Website, 2013).

The EXPLORE test is a component of the American College Testing (ACT) College and Career Readiness System and serves as the initial benchmarking assessment of ACT's Educational Planning and Assessment System (EPAS). The assessment was first administered in 1992 and can serve as a standalone assessment or as a point of entry into the secondary-school level of ACT's College and Career Readiness System (ACT, 2013). The EPAS system includes the EXPLORE, PLAN, and ACT assessments. The EXPLORE assessment is administered to students during the fall of the student's eighth-grade year and again in the spring of the student's ninth-grade year. The EPAS system gives educators at the secondary level a powerful, interrelated sequence of instruments to measure student educational achievement and assess college readiness from eighth grade through twelfth grade (ACT, 2013). The EXPLORE, PLAN, and ACT assessments are scored along a common scale from 1 to 36, with the EXPLORE assessment having a maximum score of 25. Each assessment has an associated College Readiness Benchmark. Table 1 includes the College Readiness Benchmark for the EPAS mathematics assessments (ACT, 2013).

Table 1: EPAS College Readiness Benchmarks

Subject Test	**EXPLORE 8**	**EXPLORE 9**	**PLAN**	**ACT**
Math	17	18	19	22

The EXPLORE mathematics assessment is comprised of 30 multiple-choice questions classified according to the following four content areas and associated approximate proportion: pre-algebra (33%), elementary algebra (30%), geometry (23%), and statistics/probability (14%) (ACT, 2013). The questions are designed to measure a student's mathematical reasoning with questions covering the following four cognitive areas: knowledge and skill, direct application, understanding concepts, and integrating the understanding of concepts (ACT, 2013).

The reliability and validity of assessments used in research is important (Johnson & Christensen, 2012). EPAS assessments, including the EXPLORE mathematics assessment, are designed to measure student problem-solving skills and specific mathematics content knowledge as determined by analysis of the following three sources of information: instructional objectives for grades 6 through 9 for all states in the United States with available information; review of textbooks on state-approved lists for mathematics courses in grades 6 through 8; and consultation with educators at the secondary and postsecondary levels (ACT, 2013). Therefore, the EXPLORE mathematics assessment is an appropriate and valid measurement of a student's mathematical content knowledge and mathematics problem-solving ability. Reliability refers to the stability of resulting assessment scores. Psychometricians utilize a reliability coefficient to measure reliability. Coefficient scores range from zero to one, with values near one indicating greater consistency and scores near zero indicating little to no consistency (Johnson & Christensen, 2012). According to the ACT, the reliability coefficient for raw scores and scale scores for the EXPLORE grade 8 mathematics test range from 0.80 to 0.83 with a standard error of measurement ranging between 1.70 to 1.74 depending on the test form. A reliability coefficient of 0.85 and a 1.69 standard error of measurement for the EXPLORE grade 9 mathematics test form demonstrates a high level of reliability (ACT, 2013).

The results from the EXPLORE test taken in the eighth grade are used to determine student placement into mathematics courses as well as into the mathematics support program. Students obtaining a score greater or equal to 17 on the mathematics portion are enrolled into Honors Algebra 1, while students obtaining a score less than 17 on the mathematics portion are enrolled into college preparatory Algebra 1. Students obtaining a score less than or equal to 13 on the mathematics portion are scheduled into a mathematics support course in addition to Algebra 1.

Teacher Survey

The current study also collected teacher perception data regarding the implementation of CEI through the Renaissance Learning System and the effectiveness of the planned and implemented professional development. During the 2014-2015 school year all ninth-grade Algebra 1 and Honors Algebra 1 teachers were asked to complete the teacher survey. The teacher survey was constructed using the principles of questionnaire construction from Johnson and Christensen (2012, p. 164). A school district mathematics content expert was consulted to ensure the survey language was familiar to teachers and survey statements were aligned with the professional development and guidance teachers had received before and during implementation. Additionally, small focus groups of mathematics teachers at each high school campus were utilized to ensure the survey technology was both efficient and effective in collecting the information from participants.

Teacher surveys were used by the school district and, subsequently, in the current study to collect teacher perceptions of both the blended learning approach and the implementation of the Renaissance Learning System. The survey had three discrete sections. In the first section, teachers rated their level of agreement with statements focusing on the impact of the lab-rotation model and the use of the Renaissance Learning System on their students, impact of the lab-rotation model and the use of the Renaissance Learning System on their instruction, and their readiness to implement the lab-rotation model and the Renaissance Learning System. In the second section, teachers were asked to indicate the frequency (Scale: 1=never, 2=some, 3=a lot) with which they used 13 researched-based strategies divided into teacher use of strategies and student use of strategies. Last, there was one question seeking the perceptional impact of professional development in regards to Renaissance Learning and their individual teaching.

The teacher survey was an adaptation of the Hybrid Teacher Questionnaire utilized as part of the “Effects of the Kentucky Virtual Schools’ Hybrid Program for Algebra 1 on Grade 9 Student Math Achievement” study (Cavalluzzo et al., 2012, Appendix G). The questions were developed based on the desired outcomes of the implemented CEI program within the study. A draft survey was created and reviewed by two school district mathematics content area experts as well as four pedagogical experts in the field of education. These experts provided feedback on the survey that resulted in improved clarity in both the questions and the associated directions. In addition to the subject and pedagogical experts consulted, a small focus group of four school district math teachers not in the intervention group were asked to review the survey's clarity as well as to ensure the electronic survey functioned properly. The focus group consisted of two mathematics teachers from each of the school district's two high schools. One error was found in the survey. The final survey question was set up incorrectly, resulting in one individual teacher being unable to submit the survey correctly. All focus group members reported they understood the questions being asked and had no suggestions for the improvement of any specific question. Based on this feedback, the survey was edited and reformatted to facilitate participant survey completion.

Teacher surveys were used to describe differences in the treatment condition during the intervention year. Teacher surveys were electronically given using Microsoft SharePoint, which serves as the school district's communication and collaboration platform. Teachers were instructed to submit the electronic survey prior to the conclusion of the 2014-2015 school year.

Student Survey

The current study also sought to collect student perception data regarding the implementation of CEI through the Renaissance Learning System. During the 2014-2015 school year all ninth-grade Algebra 1 and Honors Algebra 1 students were asked to complete a student survey.

The student survey was constructed using the principles of questionnaire construction from Johnson and Christensen (2012, p. 164). A school district mathematics content expert was consulted to ensure the survey language was familiar to students and the statements were aligned with the goals of CEI implementation within the school district.

Student surveys were used to collect student perceptions of the blended learning approach and the implementation of the Renaissance Learning System. The survey had two discrete sections. In the first section, students rated their level of agreement with statements focusing on the impact and use of the Renaissance Learning System. In the second section, students were asked to indicate the frequency (Scale: 1=never, 2=some, 3=a lot) they the experienced eight researched-based learning strategies that were discussed with the teacher during the ongoing professional development that took place before and during implementation.

Research Design

The current study employed a causal-comparative research design. The study's purpose was to determine the effects of CEI on student achievement growth in mathematics. Data was analyzed using a variety of statistical procedures. Descriptive statistics were used to describe the characteristics of each high school, the student sample, and the student population. Analysis of Variance (ANOVA), multi-variate analysis of variance (MANOVA), and *t* tests were used to demonstrate the impact of CEI on student growth from the EXPLORE Mathematics Assessment taken during eighth grade and the EXPLORE Mathematics Assessment taken during ninth-grade for White, Black, Hispanic, mid/high income, and low income students.

In addition to the formal statistical analysis of grade 8 and grade 9 mathematics achievement as measured by the EXPLORE mathematics assessments, information was collected from teacher and student surveys and the Renaissance Learning System. This information was used to describe the extent to which the treatment was implemented with fidelity.

Only ninth-grade students enrolled in either Algebra 1 or Honors Algebra 1 during the 2013-2014 school year who also took the EXPLORE mathematics assessment in both eighth and ninth-grade were included in the analysis of student performance in the control group. Only ninth-grade students enrolled in either Algebra 1 or Honors Algebra 1 during the 2014-2015 school year who also took the EXPLORE mathematics assessment in both eighth and ninth-grade were included in the analysis of student performance of the treatment group.

Study Procedure

The current study used the following data to determine the impact of computer-enhanced instruction on student achievement: course data from each high school's student management system, student usage data from the Renaissance Learning System, teacher and student perceptional data from surveys, and EXPLORE assessment results from grade 8 and grade 9. Course data was used to align students with specific courses as well as with specific teachers so that more in-depth analysis can be done. Student usage data from the Renaissance Learning System was used as a fidelity check for student usage of the program.

The researcher obtained permission from the school district superintendent to conduct this study. The researcher used existing data that had been previously collected by the school district. No new data was collected solely for the purpose of the current study. Therefore, all data are considered extant. Student names were removed prior to the researcher's analysis of the data and the data was stored in a secured location. The researcher submitted the study proposal to Northern Illinois University IRB and thereafter received approval to proceed with the study.

CHAPTER FOUR

RESULTS

The purpose of this study was to examine whether the use of computer-enhanced instruction (CEI) impacted student mathematics achievement. The use of CEI was the independent variable in this study and academic achievement on the math portion of the EXPLORE exam was the dependent (outcome) variable.

Preliminary Analyses

Prior to completing the primary, proposed data analyses, descriptive statistics were conducted. Information about the sample is presented in Tables 2 – 7.

Table 2. Number of Students in Control and Intervention Groups

	N	Percent
Control Group	1453	51.4
Intervention Group	1374	48.6
Total	2827	100.0

Table 3. Total Number of IEP'd Students in the Sample

	N	Percent
No IEP	2488	88.0
Yes IEP	339	12.0
Total	2827	100.0

Table 4. Gender for Total Sample

Gender	N	Percent
Male	1449	51.3
Female	1378	48.7
Total	2827	100.0

Table 5. Race for Total Sample

Race	N	Percent
American Indian	14	.5
Asian	29	1.0
Black	798	28.2
Latino	1261	44.6
Multiracial	1	.0
Pacific Islander	1	.0
White	723	25.6
Total	2827	100.0

Table 6. Free and Reduced Lunch Status for Total Sample

	N	Percent
No FRL	901	31.9
Yes FRL	1926	68.1
Total	2827	100.0

Table 7. Type of Algebra Course Taken for Entire Sample

Type of Course	N	Percent
Algebra 1 Part 1 Fund (SPED)	34	1.2
Algebra 1 Part 1 Instr (SPED)	143	5.1
Algebra 1	2364	83.6
Algebra 1 (Bilingual)	74	2.6
Algebra 1 Honors	212	7.5
Total	2827	100.0

Primary Data Analysis

Research Question 1: Are there differences in the amount of student mathematics achievement growth between the control group and the student treatment group receiving computer-enhanced instruction (CEI) as measured by the math EXPLORE test of ninth-grade Algebra 1 students?

Hypothesis 1: The use of CEI with ninth-grade Algebra 1 students positively impacts student mathematics achievement as measured by the EXPLORE mathematics assessment. ---Not Supported.

Research Question 2: Are there differences in the amount of student mathematics achievement growth between the control student group and the student treatment group receiving computer-enhanced instruction (CEI) as measured by the math EXPLORE test of ninth-grade Honors Algebra 1 students?

Hypothesis 2: The use of CEI with ninth-grade Honors Algebra 1 students will positively impact mathematics achievement as measured by the math EXPLORE assessment. ---Not Supported.

In order to examine research questions one and two and the corresponding hypotheses, a series of ANOVAs were conducted. The IV in the analysis was group participation (control vs. treatment) and the DV was the math EXPLORE test change score from 8^{th} grade to 9^{th} grade, a measure of growth from one test administration to the next. The IV was examined for several different groups; Overall, Special Education, Algebra 1, Bilingual Algebra, and Honors Algebra. No significant differences between the treatment and control groups were found for the Special Education and Bilingual Algebra groups. However, for both the Algebra 1 and Honors Algebra groups, the respective ANOVAs were significant, but not in the direction hypothesized. Specifically, for both Algebra 1 and Honors Algebra, the control group outperformed the treatment group with respect to EXPLORE change scores. Please see Table 8 for results of all ANOVA results for all groups.

Table 8. ANOVA Results by Algebra Class

Group (IV)	df	F	*p* value
Overall	1, 2365	51.63	.000
Special Education	1, 109	.41	.52
Algebra 1	1, 1978	48.76	.000
Bilingual Algebra	1, 46	.848	.36
Honors Algebra	1, 198	14.64	.000

Research Question 3: Are there differences in the amount of student mathematics achievement growth between the control student group and the student treatment group receiving computer-enhanced instruction (CEI) as measured by the math EXPLORE test of ninth-grade students who enter high school performing below grade level in mathematics?

Hypothesis 3: The use of CEI with ninth-grade Algebra 1 students who enter high school performing below grade level in mathematics positively impacts student mathematics achievement as measured by the math EXPLORE test. ---Not Supported.

In order to examine this research question and the corresponding hypothesis, an ANOVA was conducted. The IV in the analysis was group participation (control vs. treatment) for below grade level students and the DV was the math EXPLORE change score for below grade level students. Below grade level students were defined as students who score 15 or below on the 8th grade EXPLORE exam. Results of the ANOVA were significant, but not in the direction hypothesized. Specifically, the control group (M=1.17, s.d. = 2.45) outperformed the treatment group (M=.63, s.d. = 2.54) with respect to EXPLORE change scores, $F(1, 1490) = 17.41$, $p < .001$.

Research Question 4: Are there differences in the amount of student mathematics achievement growth between Algebra 1 students whose teachers regularly utilize computer-enhanced instruction (CEI) as a pedagogy within their Algebra 1 course and students whose teachers who do not regularly use CEI within their Algebra 1 course as measured by the Educational Planning and Assessment (EPAS)?

Hypothesis 4: Algebra students with teachers who regularly utilize CEI as a component within their Algebra course will show more growth math EXPLORE test. --- Supported

In order to examine this research question and hypothesis, a *t t*est was conducted. Teacher utilization of the program was categorized into high use and low use based upon teacher response of "Strongly Disagree or Disagree" they used the system at least three times per week (for the low-use group) vs. those who selected "Agree or Strongly Agree" they used the system three times per week (for the high-use group). Group membership (high vs. low) served as the IV for the analysis. The DV was the score on the last math EXPLORE test taken, in this case, the 9th Grade EXPLORE test. In addition, a second *t* test was conducted utilizing the same IV but the DV was the change scores on the math EXPLORE test. Results of both *t* tests indicated significant results. Specifically, the high-use group (M=14.16, s.d. = 2.52) outperformed the low-use group (M=13.37, s.d. = 2.74) on the 9th grade EXPLORE test, $t(643) = -3.44$, $p < .01$.

Similarly, when change scores from 8^{th} to 9^{th} grade were examined, the high-use group (M=.96, s.d. = 2.51) outperformed the low-use group (M=.45, s.d. =2.53), *t* (643) = -2.37, *p*<.05.

Research Question 5: Are there differences in the amount of student mathematics achievement growth between Algebra 1 students whose teachers self-report a positive perception of computer-enhanced instruction (CEI) and students whose teachers self-reported a negative perception of CEI as measured by the math EXPLORE test?

Hypothesis 5: Algebra students with teachers who have a positive perception of CEI will show more growth on the math EXPLORE test than students with teachers who have a negative perception of CEI. ---Emerging Support.

Similar to Research Question 4, in order to examine this research question and hypothesis, *t* tests were conducted. Self-reported teacher data through the use of a survey was used to categorize teachers into either having a positive perception of Renaissance Learning or having a negative perception of the program. This served as the IV for the analysis. The DV was the test score on the last math EXPLORE test taken. In addition, a *t* test was conducted utilizing the same IV but the DV was the change scores on the math EXPLORE test. Results of both t-tests were not significant, but were approaching significance. Specifically, the positive perception group (M=14.10, s.d. = 2.32) outperformed the negative perception group (M=13.23, s.d. = 2.89) on the 9^{th} grade EXPLORE test, *t*(642)= -3.76, *p* = .11 Similarly, when change scores from 8^{th} to 9^{th} grade were examined, the positive perception group (M=.80, s.d.=2.30) outperformed the negative perception group (M=.46, s.d.=2.67), *t* (642)= -1.62, *p*=.09.

Research Question 6: Are there differences in the amount of student mathematics achievement growth between Algebra 1 students whose teachers self-report a more student-centric instructional approach and students whose teachers self-report a more teacher-centric instructional approach as measured by the math EXPLORE test.

Hypothesis 6: Algebra students with teachers who have a more student-centric instructional approach will show more growth on the EXPLORE mathematics assessment than students with teachers who have a more teacher-centric instructional approach. ---Not Supported

Similar to Research Questions 4 and 5, in order to examine this research question and hypothesis, *t* tests were conducted. Self-reported teacher data through the use of a survey was used to categorize teachers into either having a student-centered pedagogical approach while using the program vs. a teacher-centered pedagogical approach while using the program. A Pedagogy Subscale was created by combining questions 19, 20, 21, 24, and 27. Together, these questions had an internal consistency coefficient of .75. Scores on this subscale where then split into quartiles. Scores at the lowest quartile and below served as the “teacher centric” categorization, whereas scores at the highest quartile and above served as the “student centric” categorization. This served as the IV for the analysis. The DV was the score on the last math EXPLORE test taken. In addition, a *t* test was conducted utilizing the same IV but the DV was the change scores on the math EXPLORE assessment. Results of both *t* tests were not significant. Specifically, there were no differences between teacher centric group (M=13.44, s.d. = 2.65) and the student centric group (M=13.54, s.d. = 2.71) on the 9^{th} grade EXPLORE test, $t(479)= -.392$, $p = .70$ Similarly, when change scores from 8^{th} to 9^{th} grade were examined, there were no differences between the teacher centric group (M=.48, s.d.=2.52) outperformed the student centric group (M=.54, s.d.=2.60), $t\ (479)= -.22$, $p=.83$.

Summary

The purpose of this study was to examine whether the use of computer-enhanced instruction (CEI) impacts student mathematics achievement. Additionally, factors such as teacher perception, course level, and technology efficacy of teachers were explored to determine whether they are related to mathematics achievement. The results of the various analyses showed there is not a positive relationship between the use of computer-enhanced instruction and mathematics achievement between the control and the treatment group. However, the analysis did demonstrate there was a positive relationship that was significant between the higher use of CEI and mathematics achievement of students who were in the treatment group. The analysis also demonstrated that there was emerging support for a positive relationship that approached significance between teachers having positive perceptions of CEI and mathematics achievement of students who were in the treatment group. These findings are discussed in the next chapter.

CHAPTER FIVE

FINDINGS, DISCUSSION, RECOMMENDATIONS, AND CONCLUSIONS

Mathematics achievement has and will continue to be a dominant point of discussion within state and national reform initiatives (National Commission on Excellence in Education, 1983; National Research Council, 1989; NCTM, 1989, 2000; National Mathematics Advisory Panel, 2008; Daun-Barnett & St. John, 2012). Though the high school mathematics graduation requirements have increased, many students struggle to demonstrate mastery of mathematics concepts (Daun-Barnett & St. John, 2012; U.S. Department of Education, 2014; Zelkowski, 2010). Educational leaders must determine how student mathematics achievement can be maximized with fewer teacher, more students, and less financial support.

This study was exploratory in nature and contributes to the limited existing research in the area of computer-enhanced instruction (CEI) and student mathematics achievement. This chapter presents a summary of the current research study and its findings. Conclusions and implications of the findings will be discussed, including limitations. Additionally, recommendations for further research are presented.

Summary of Findings

This study sought to determine whether the use of computer-enhanced instructional (CEI) impacted student mathematics achievement. Additional variables were also explored to determine their impact upon student mathematics achievement within the treatment group: categorization of teachers as high or low use as well as teachers having a negative or positive perception of the Renaissance Learning System. Descriptive and inferential statistics were utilized to answer each of the research questions. The study's achievement outcome measure was the EXPLORE Assessment that is part of the ACT's Educational Planning and Assessment System (EPAS),a longitudinal assessment system that allows teachers and school administrators to track student academic growth and achievement (Allen et al., 2009). Teacher and student surveys were also utilized to gather perceptional data.

The first and second research questions sought to determine whether there were differences in the amount of mathematics achievement growth between control and the treatment groups receiving computer-enhanced instruction (CEI) as measured by the MATH EXPLORE scores of ninth-grade Algebra 1 students and Honors Algebra 1 students respectively. The independent variable was the use of CEI. Student achievement was measured by the change score of the mathematics portion of the EXPLORE assessment between the EXPLORE test that was taken both during eighth grade and ninth-grade. The research questions were examined and the control groups outperformed the treatment groups for both the Algebra 1 and Honors Algebra 1 courses. Therefore, both associated hypotheses were rendered null. In this study, the use of CEI did not improve student mathematics achievement of Algebra 1 or Honors Algebra 1 students.

The third research question sought to determine whether there were statistically significant differences in the amount of student mathematics achievement growth between the control and treatment group receiving computer-enhanced (CEI) as measured by the change in MATH EXPLORE scores of ninth-grade students who entered high school below grade level. The research question was examined and there a statistically significant difference was found. Similar to the first and second research question, the control group outperformed the treatment group. Therefore, the hypothesis was rendered null. In this study, the use of CEI did not significantly improve mathematics achievement of ninth-grade students entering high school below grade level as measured by MATH EXPLORE change scores.

The fourth research question explored whether there were differences in the amount of student mathematics achievement growth between Algebra 1 students whose teachers regularly utilize computer-enhanced instruction (CEI) as a pedagogy within their Algebra 1 classroom instruction and students whose teachers do not regularly use CEI within their Algebra 1 as a component of their classroom pedagogy as measured by the change in MATH EXPLORE scores. It was hypothesized students whose teachers regularly utilized CEI would show more growth. Self-reported teacher data gathered through the use of a survey was used to categorize teachers into a high-use or low-use designations. Teachers were categorized into high-use or low-use categories based on self-reported data collected through the teacher survey. Specifically, teachers rated themselves using 1 through 4 based on the statement, "My students use the Renaissance Learning System a minimum of 3 times per week." Teachers selecting either 1 or 2 were designated as low users and teachers selecting either 3 or 4 were designated as high users. Results of the analyses were statistically significant. Therefore, the findings regarding this research question support the hypothesis that greater use of CEI as a pedagogical classroom strategy was related to increased mathematics achievement as measured by MATH EXPLORE change scores.

The fifth research question sought to determine whether there were differences in student mathematics achievement between Algebra 1 students whose teachers self-reported a positive perception of computer-enhanced instruction (CEI) and students whose teachers self-reported a negative perception of CEI as measured by the change in MATH EXPLORE scores. Self-reported teacher data through the use of a survey was used to categorize teachers into either positive or negative perception categories. No significant relationship was found. However, the results approached significance. Although teacher perceptions of CEI were not found to have a relationship to mathematics achievement as measured by MATH EXPLORE change scores, because this is a newer area of research coupled with results that approached significance, additional research is warranted.

The sixth and final research question sought to determine if there were differences in the amount of student mathematics achievement growth between Algebra 1 students whose teachers self-reported a more student-centric instructional approach and students whose teachers self-report a more teacher-centric instructional approach. Self-reported teacher data gathered through the use of a survey was used to categorize teachers into a student-centric vs. teacher centric pedagogical categories. No significant differences were found. As such, instructional approach did not impact math achievement in this sample.

Discussion

As demonstrated through the review of previous research, there has not been extensive investigation of blended learning (Cavalluzzo et al., 2012; U.S. Department of Education, 2010; Picciano, 2009). Furthermore, research that has been conducted in the areas of computer assisted instruction (CAI) and computer-enhanced instruction (CEI) and mathematics achievement has, to-date, yielded mixed results (Campuzano et al., 2009; Cheung & Slavin, 2013; Cuban & Kirkpatrick, 1998; Dynarski et al., 2007; Hadjerrouit, 2011; Kulik, 2002; Kulik & Kulik, 1991; Murphy et al., 2002; O’Dwyer et al., 2007). Therefore, although the analyses within this study supported only 1 of the 6 hypotheses, the findings of this study should be examined and discussed.

The research findings were clear with respect to student mathematics achievement and the use of CEI. Regardless of whether students entered high school below grade level or were placed in a more rigorous mathematics course, the use of CEI did not positively impact mathematics achievement, as evidenced by the control group outperforming the treatment group in all subgroups. However; further research examined whether any differences existed within the treatment group between students who had teachers categorized as high use or low use of CEI. Here, the study found students in high-use classrooms had a slightly higher mean change score than students in low-use classrooms.

These findings are similar to the results found by Cavalluzzo et al. (2012). Cavalluzzo et al. conducted a study analyzing the effectiveness of the Kentucky Virtual Schools' hybrid program for Algebra 1. The study included 25 schools (13 treatment and 12 control) in 2007-2008 and 22 schools (11 treatment and 11 control) in 2008-2009 from a volunteer sample of 47 schools participated (p. 10). All schools in the study volunteered for participation, with schools randomly assigned to the treatment or control groups. All Algebra 1 teachers and students in a school were assigned to the school's treatment group. This group included "professional development and materials for all participating teachers and follow-up support throughout the year" (p. 13). The researchers found no statistically significant effect upon student achievement either as a whole or by student gender, student cohort, or school rural status (p. xii). Within the summary findings, Cavalluzzo et al. (2012) included limitations due to fidelity of implementation explaining that many teachers within the treatment group failed to attend professional development sessions (p. 75). Another limitation was an earlier version of the student courseware, containing numerous errors, was installed (Cavalluzzo, 2012). Similar limitations are found within the current study.

When reviewing the study's findings consideration must include research conducted on the importance of technology, pedagogy, and content knowledge of teachers implementing technology in their classrooms (Drijvers, 2013; Gul, 2015; Harris & Hofer, 2011). Second, research associated with the technology acceptance model (TAM) may provide insight on user acceptance of technology and the relationship to intended use of technology (Davis, 1985). Last, research associated with professional development and technology implementation may also provide pertinent information in regards to the findings within this current study (Schrum & Levin, 2013).

The teachers in the high-use category may have had higher technology self-efficacy and/or more positive perceptions of the usefulness of the technology they were using with their students. Additionally, the possible lack of technology self-efficacy of teachers within the low-use category may have contributed to the study's overall findings. Bandura's (1993) self-efficacy theory proposed an individual's perceived self-efficacy influences four major processes; cognitive, motivational, affective, and selection. "Teachers with a strong sense of individual efficacy tend to spend more time planning, designing, and organizing what they teach" (Zambo & Zambo, 2008).

Teacher technology self-efficacy has also been associated with teacher use of technology (Holden & Rada, 2011). Teacher technology self-efficacy is multi-faceted as found by Guerrero (2010):

> The knowledge needed to effectively employ technology as part of mathematics instruction includes technology-specific management, instructional, and pedagogical knowledge; increased mathematics subject-matter knowledge; and knowledge of when and how to best to use technology to support mathematics instruction. (p. 134)

According to Holden and Rada (2011), "User acceptance, satisfaction, and perceived usability of innovative technologies are crucial to the diffusion of those technologies" (p.343). Holden and Rada (2011) collected self-reported survey data and found technology self-efficacy influenced perceived ease of use and usability, though the researchers acknowledged findings may vary based upon the population studied and the specific type of technology studied. As previous research has shown a lack of technology self-efficacy may have contributed to outcomes in the current study (Holden & Rada, 2011; Guerrero, 2010; Moore-Hayes, 2011).

In addition to teacher technology self-efficacy, perceived ease of use and perceived usefulness of technology may also be related to the findings in this current study. A study in Sweden was conducted with 84 student teachers to determine what, if any, relationship existed between the use of technology and perceived usefulness of technology, perceived ease of use of technology, or external expectations to use technology (Ma, Andersson & Streith, 2005). The researchers found teacher perception of usefulness had a direct significant effect on intended use of technology and perceived ease of use had an indirect significant effect on the intended use of technology. Ma et al. (2005) did not find that external expectations for use of technology had an effect on the intended use of technology. Additionally, a study was conducted with 764 elementary and secondary teachers in Quebec to investigate the "motivational, demographic, and school conditions, which relate to teachers' implementation of computer technology" (Wozney, Venkatesh, & Abrami, 2006, p. 192). The researchers found teacher motivation to use technology and the amount of technology related professional development was significantly related to computer use in the classroom. The study further indicated "our findings suggest that professional development must attend to the enhancement of teachers' expectations of success" (p. 195). Therefore, while external expectations for use of technology may not have an effect on use, internal expectations of teachers have been shown to be related to higher implementation levels (Ma et al., 2005; Wozney et al., 2006).

Internal expectations and beliefs of teachers can be examined using the technology acceptance model (TAM). Research associated with the TAM may also provide insight on user acceptance of technology as well as use of technology (Davis, 1985). The TAM model proposes motivation to use a specific technology is based upon an individual's perceived usefulness, perceived ease of use, and attitude toward using the technology. Information from the TAM studies demonstrate the importance of professional development, that focuses on the specified cognitive beliefs (i.e., perceived usefulness and perceived ease of use) and also upon external factors such as self-efficacy, anxiety, and motivation, that are essential for successful implementation of technology initiatives within schools (Holden & Rada, 2011; Zambo & Zambo, 2008).

Another important factor that must be acknowledged is professional development (Schrum & Levin, 2013). The importance of professional development associated with technology integration has been demonstrated through research (Pan & Franklin, 2011; Overbaugh & Lu, 2008). A key finding in many research studies regarding the implementation of technology discusses the importance of planning and implementing professional development in terms of the technological-pedagogical content knowledge (TPACK) model (Drijvers, 2013; Gul, 2015; Harris & Hofer, 2011), which is an adaptation of Shulman's (1986) pedagogy and content knowledge (PACK) model. The TPACK model applied to professional development focuses on the importance of the individual's intersection of knowledge and skill in all three areas: technology, pedagogy, and content (Harris & Hofer, 2011). Drijvers (2013) states, "the integration of technology in mathematics education is not a panacea that reduces the importance of the teacher---rather, the teacher has to orchestrate learning" (p. 15). Additionally, it is important to recognize mathematics teachers have various needs depending upon their knowledge in the three TPACK model areas and require differentiated professional development to meet their needs (Clark-Wilson, Hoyles, Noss, Vahey & Roschelle, 2015).

Vannatta and Fordham (2004) conducted a study of 177 K-12 teachers from six northwest Ohio schools and found technology training, time commitment to teaching, and openness to change are predictors of technology use. They recommend that technology training include teachers' personal experience with technology, participant reflection, demonstrations of effective use of technology, collaboration with colleagues, examination of individual dispositions relating to technology, a positive leader, and the modeling of risk-taking behaviors with technology (Vannatta & Fordham, 2004). Fethi and Lowther (2010) conducted a study that included 1,382 teachers from 54 schools launching a new technology initiative and found computer proficiency and teachers' beliefs and readiness positively influence technology integration. Therefore, school leaders must be mindful of the professional development that is planned and implemented in regards to technology integration within the classroom because research has demonstrated that teacher perceptions about the technology influence the intended use of technology (Bennison & Goos, 2010; Holden & Rada, 2011; Ma et al., 2005; Venkatesh & Davis, 2000;).

As stated previously, CEI use did not positively impact mathematics achievement, as evidenced by the control group outperforming the treatment group in all subgroups studied. The discussion of this data must include possible implementation issues that may not have been considered previously. Though teachers within the current study were invited to provide input for the web-based learning platform that was implemented, not all mathematics teachers provided input. Additionally, a survey was not conducted prior to implementation to solicit teacher perceptions regarding the technology and the training that was provided was not differentiated based on teacher readiness or level of technology skills. Therefore, teachers having either a negative perception of the technology selected for implementation or low readiness levels could have yielded low levels of implementation. The current study did produce results demonstrating blended learning has a positive relationship upon student mathematics achievement. However, there is a limited body of research and the existing research has yielded mixed results. According to Learning Forward "Professional Development is a comprehensive, sustained and intensive approach to improving teachers' and principals 'effectiveness in raising student achievement" (2001). Though teachers in the current study had professional development sessions regarding the web-based platform prior and during implementation, the quality of the professional development was not evaluated as part of the study.

In conclusion, in order to adequately explore the application of blended learning in the secondary mathematics classroom, teacher technology self-efficacy and technology readiness must be incorporated into the implementation model. Professional development that is differentiated to meet the needs of specific teachers must be planned, implemented, and evaluated.

Limitations

This section identifies and discusses the study's limitations that may have contributed to the results that were not statistically significant in all tested hypotheses. Limitations include the use of self-reported data, missing survey data from students and teachers, missing assessment data from students, variance of teachers within the study and lack of implementation of CEI during the study.

The first limitation within this study was the use of self-reported data. Teacher surveys were utilized as part of this study. Though the survey information provided additional depth to the study and allowed for various statistical comparisons within the treatment group, this type of data is subjective and can be highly variable based on individual perceptions.

The second limitation was missing survey data from students and teachers. Again, the use of student and teacher data provided for additional statistical comparisons within the treatment group; however, the comparisons could be done only for those teachers and students who completed the surveys. Because the survey completion rate was not 100%, key perceptions may have been missing that may have impacted the findings within the study.

Missing student assessment data was also a limitation. Only students who had taken both the EXPLORE test in eighth grade and the EXPLORE test in ninth-grade were included in the study. Therefore, students with missing scores were excluded from the study. Therefore, the impact of CEI upon these particular students could not be part of the research study.

The fourth limitation was the variance among the teachers who participated in this study. Though the curricula for both the control group and the treatment group was consistent, there were some variations among the teachers in both cohorts that could have impacted the findings.

The fifth limitation was students had difficulty accessing the web-based platform remotely in the evenings during the early stages of implementation. Multiple student and teacher complaints were received. It was determined the vendor was performing upgrades to the product in the evening, at times when students were attempting to access the program.

A final limitation that cannot be ignored was the varied level of CEI implementation during the study that was demonstrated through both the teacher and student surveys.

Recommendations

Mathematics achievement has and will continue to remain central to both national and local reform initiatives (National Commission on Excellence in Education, 1983; National Research Council, 1989; NCTM, 1989, 2000; National Mathematics Advisory Panel, 2008; Daun-Barnett & St. John, 2012). Therefore, school leaders must continue to focus on increasing the proportion of students who are college and career ready in the area of mathematics.

Professional development must be the focal point for all educational leaders hoping to positively impact student achievement (Lustick & Sykes, 2006). As previously stated, there is limited guidance for school leaders regarding types of teacher professional development that has positively impacted student mathematics proficiency (Gersten et al., 2014). John Hattie (2012) states “that there is a ‘practice’ of teaching,” intentionally asserting that teaching is not science (p. 5). Hattie (2012) further explains there is no fixed guidance that has been shown to maximize achievement for every student. Therefore, continual growth and learning for teachers is significant since the teacher in front of students is one of the few variables that educational systems can control (Maldonado & Victoreen, 2002; Guskey, 2005; Holloway, 2006). Furthermore, as previously stated, many of today’s learning structures and practices would be recognizable to students educated in the early to mid-19th century (Horn, 2010; Keller et al., 2005). In addition, many aspects of the manner educators are trained are also reminiscent of training programs developed during the Industrial Age (Reigeluth, 2001). Therefore, if educational leaders hope to impact student achievement through local initiatives, greater attention must be placed on designing effective professional development (Hawley & Valli, 2000; Ingvarson, 2005).

Hawley and Valli (2000) provide the following nine guidelines for effective professional development:

> Content focuses on what students are to learn and how to address the different problems students may have in learning that material; driven by analyses of the differences between (a) goals and standards for learning and (b) student performance; involves teachers in the identification of what they need to learn and, when possible, in the development of the learning opportunity and/or the process to be used; is primarily school based and integral to school operations; provides learning opportunities that relate to individual needs but are, for the most part, organized around collaborative problem solving; is continuous and ongoing, involving follow-up and support for further learning; incorporates evaluation of multiple sources of information on outcomes for students and processes that are involved in implementing the lessons learned through professional development; provides opportunities to engage in developing a theoretical understanding of the knowledge and skills to be learned; and should be integrated with a comprehensive change process that addresses impediments to and facilitators of student learning. (p. 1-4)

The relationships among effective professional development, content knowledge, pedagogical knowledge, technology knowledge, and teacher efficacy cannot be ignored (Ertmer & Ottenbreit-Leftwich, 2010). Maldonado and Victoreen (2002) stated “Content-specific material holds extra importance for the teaching of mathematics and science” (p. 7). Therefore, deep connections to core concepts in mathematics as well as how to teach specific content to specific learners must be considerations as professional development is planned and implemented for mathematics teachers. Koehler, Mishra and Cain (2013) describe the Technological Pedagogical Content Knowledge (TPACK) framework that builds upon Lee Shulman’s (1986) Pedagogical Content Knowledge (PCK) framework. Koehler et al. (2013) suggests that teachers must be extremely knowledgeable in all three areas and that fluent knowledge allows teachers to leverage technology and maximize student learning (Kazu & Erten, 2014).

Understanding and implementing effective professional development focused upon increasing teacher self-efficacy in content, pedagogy, and technology is vitally important and must be an essential component of all education initiatives seeking to improve student achievement.

Future Research

Additional research in the area of computer-enhanced instruction (CEI) should occur. However, it is recommended that this research include more in-depth fidelity measures such as teacher and student interviews as well as survey data throughout the implementation process. It is also recommended that data from another cohort of students be collected and analyzed from the 2015-2016 school year to provide local educators with additional data from which conclusions can be drawn and decisions can be made.

This study was primarily a quantitative analysis based on standardized achievement data. The literature is clearly shows there are multiple barriers to technology implementation, including teacher efficacy in the area of technology. Therefore, a qualitative analysis to identify barriers that may impact implementation of blended learning models would be appropriate from both the teacher and student perspective.

Based on the perceptional data from teachers that was gathered through this study, it is recommended the impact of additional CEI professional development modeled from the framework of Hawley and Valli (2000) as well as the TPACK framework from Koehler be studied further due to limited guidance for school leaders on the types of teacher professional development that has positively impacted student mathematics proficiency (Gersten et al., 2014). This would provide both teachers and administrators valuable information.

Conclusion

This quantitative non-experimental dissertation explores the impact of disruptive innovation theory in the form of computer-enhanced instruction (CEI) upon mathematics achievement. It also examines both teacher and student perceptions of CEI implementation in high school mathematics classrooms and the impacts of CEI upon student mathematics achievement. The study includes two cohorts of ninth-grade students in a suburban public high school district located southwest of Chicago, Illinois. The study spanned the 2013-2014 and 2014-2015 school years. The first student cohort was the pre-intervention or control group and included students who were enrolled in Algebra 1, Honors Algebra 1, or Algebra 1 Support during the 2013-2014 school year. The second student cohort was the intervention group comprised of students who were enrolled in Algebra 1, Honors Algebra 1, or Algebra 1 Support during the 2014-2015 school year.

This study did not find CEI to have a statistically significant impact upon student mathematics achievement. However, the study used a survey to gather self-reported teacher data and this data was used to categorize teachers into either a high-use or low-use CEI group. Teachers in the high-use group demonstrated a statistically significant higher mean change score for student achievement.

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APPENDIX A

TEACHER SURVEY

Teacher Survey

Please indicate your level of agreement with the following statements by rating each one of the statements below. *

	Strongly Disagree 1	2	3	Strongly Agree 4
1. Use of the Renaissance Learning System is effective for helping students learn key algebraic concepts.	○	○	○	○
2. My teaching is student-centered when I use the Renaissance Learning System.	○	○	○	○
3. The Renaissance Learning System includes helpful learning activities.	○	○	○	○
4. The JTHS created libraries within the Renaissance Learning System effectively covers the knowledge and skills students need to make gains on the EXPLORE 9 Math assessment.	○	○	○	○
5. Student interest and engagement are high when I use the Renaissance Learning System.	○	○	○	○
6. The difficulty level of Accelerated Math is appropriate for most of my students.	○	○	○	○
8. I have received adequate training to effectively teach using the Renaissance Learning System.	○	○	○	○
9. My students use the Renaissance Learning System a minimum of 3 times per week.	○	○	○	○
10. The amount of academically focused class time is high when I use the Renaissance Learning System.	○	○	○	○
11. I have the essential algebra knowledge and skills needed to conduct classes that implement the Renaissance Learning System.	○	○	○	○
12. I have the essential technology knowledge and skills needed to conduct classes that implement the Renaissance Learning System.	○	○	○	○
13. I can readily obtain answers to questions regarding implementation of the Renaissance Learning System.	○	○	○	○
14. I use computers on a weekly basis to provide differentiated instruction that is based on individual learner needs.	○	○	○	○

While implementing the Renaissance Learning System this year how often did YOU do the following during DIRECT instruction? *

	Never 1	At least 1 to 2 times weekly 2	At least 3 to 5 times weekly 3
15. Ask "Why?" and "What if?" questions	○	○	○
16. Use number lines, graphs, or diagrams to explain algebra	○	○	○
17. Use a computer to explain algebra	○	○	○
18. Facilitate student led discussions about a specific algebra concept	○	○	○

How often did YOUR STUDENTS do the following during the 2014-2015 school year? *

	Never 1	At least 1 to 2 times weekly 2	At least 3 to 5 times weekly 3
19. Work in like ability groups	○	○	○
20. Work in different ability groups	○	○	○
21. Write to explain algebra (descriptions, poetry, songs, reflections)	○	○	○
22. Talk to explain algebra	○	○	○
23. Use manipulatives such as algebra tiles or blocks	○	○	○
24. Use activities such as estimating or drawing	○	○	○
25. Use graphing calculators	○	○	○
26. Use computers to learn algebra	○	○	○
27. Use "exit slips" (pencil/paper or any other method)	○	○	○

Please use the scale that follows to answer the question below. *

	Little 1	Some 2	A lot 3
To what degree did implemented professional development associated with Renaissance Learning impact the way you teach algebra?	○	○	○

Finish Cancel

APPENDIX B

STUDENT SURVEY

Student Survey

Please indicate your level of agreement with the following statements. *

	Strongly Disagree 1	2	3	Strongly Agree 4
1. The Renaissance Learning System helped me learn.	○	○	○	○
2. I used Renaissance at least 3 times per week during math class.	○	○	○	○
3. My math teacher uses computers with students on a weekly basis during my math class.	○	○	○	○

How often did you do the following during your math class during the 2014-2015 school year? *

	Never 1	At least 1 to 2 times weekly 2	At least 3 to 5 times weekly 3	N/A
4. Work in groups	○	○	○	○
5. Write to explain how I solved an algebra problem	○	○	○	○
6. Draw to solve an algebra problem or to explain an algebra concept	○	○	○	○
7. Talk to other students or my algebra teacher to explain an algebra concept	○	○	○	○
8. Use graphing calculators	○	○	○	○
9. Use computers to learn algebra	○	○	○	○
10. Use Renaissance outside of algebra class	○	○	○	○
11. Complete "exit slips" or "tickets out the door" at the end of my algebra class	○	○	○	○

Finish Cancel

APPENDIX C

OFFICE OF RESEARCH COMPLIANCE INSTITUTIONAL REVIEW BOARD NOTICE

Determination Notice

Activity Does Not Meet the Definition of "Human Subjects Research"

22-Oct-2015
Karla Guseman
Leadership, Educational Psychology and Foundations

RE: Protocol # **HS15-0319** "**Increased personalization through the use of technology in the secondary mathematics classroom**"

Dear Karla Guseman,

The above activity was reviewed on **22-Oct-2015**. From the information that has been provided to the Office of Research Compliance, the proposed activity does not meet the definition of human subjects research, as defined in 45 CFR 46.102, and is not subject to oversight by the Institutional Review Board.

Research means a systematic investigation, including research development, testing and evaluation, designed to develop or contribute to generalizable knowledge.

Human subject means a living individual about whom an investigator (whether professional or student) conducting research obtains

(1) Data through intervention or interaction with the individual, or
(2) Identifiable private information.

Intervention includes both physical procedures by which data are gathered (for example, venipuncture) and manipulations of the subject or the subject's environment that are performed for research purposes. *Interaction* includes communication or interpersonal contact between investigator and subject. *Private information* includes information about behavior that occurs in a context in which an individual can reasonably expect that no observation or recording is taking place, and information which has been provided for specific purposes by an individual and which the individual can reasonably expect will not be made public (for example, a medical record). Private information must be individually identifiable (i.e., the identity of the subject is or may readily be ascertained by the investigator or associated with the information) in order for obtaining the information to constitute research involving human subjects.

If you have questions or need additional information, please contact the Office of Research Compliance at 815-753-8588.

Sincerely,
Jeanette Gommel
Office of Research Compliance