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Impact of Mathematics Computer-Assisted Instruction on English Language Learner Achievement

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Achievement

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of the requirements for the degree of
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by

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Abstract

This quasi-experimental study examined the effect of supplemental mathematics computer-assisted instructional programs on the achievement of students in grades three and four over a two year period. This study evaluates the computer-assisted instruction (CAI) supplemental interventions through the lens of the sheltered instruction approach to teaching English Language Learner (ELL) students. The students who took part in the intervention attended nine elementary schools in one Arkansas district in the 2011-2012 and 2012-2013 school years. Data from Measures of Academic Progress (MAP) assessments were analyzed using a factorial ANOVA with pretest and two posttests over the course of two school years. Data variables included ELL status and method of instruction CAI v Traditional Instruction (TI). This study sought to determine the impact CAI programs had on the math MAP RIT scores of third and fourth grade students in the district. Both ELL and non-ELL students were included in the study to determine if the CAI programs were more successful with either group. Results indicated that use of CAI does not exact significantly different math achievement scores than TI alone, according to math MAP RIT scores. Results were analyzed using an Analysis of Variance (ANOVA) with repeated measures for two different factors. The TIME*ELL*CAI interaction was not significant, however, the main effect of group (ELL) was significant, as was the effect of time. Post hoc contrasts found that math scores for all groups at the follow up sessions were significantly higher than scores observed at baseline.

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Table of Contents

CHAPTER 1: INTRODUCTION

Background

Poor mathematics achievement in United States schools is an area of great concern for educators across the nation. Phillips (2007) found that 78% of adults could not explain how to compute the interest paid on a loan, 71% could not calculate miles per gallon on a trip, and 58% could not calculate a 10% tip for a lunch bill. The issue is even more pronounced for English Language Learners (ELLs) The National Center for Educational Statistics (NCES), 2004, Secada et al., (1998). Mathematics curricula contains highly technical vocabulary that is difficult for ELL students who have limited or no prior experience with such content in their native language (Echevarria, Short, & Powers, 2006; Echevarria, Vogt, & Short, 2000). This dissertation examined the problem of poor mathematics achievement by ELL students, and explored several supplemental computer-assisted instruction (CAI) interventions that were designed to aid students in performing on grade-level. Further, this study inspected the CAI implementation at one suburban school district to determine if the CAI supplement had an impact on achievement when compared to traditional instruction (TI) alone.

Leading educators of ELL students recommend meaningful supplemental materials, used to a high degree to support the curriculum as a part of sheltered instruction best practices (Echevarria, Vogt, & Short, 2013). This included technology and digital learning that "specifically provide the opportunity for increased equity and access; improved effectiveness and productivity of teachers and administrators; and improved student achievement and outcomes" (Alliance for Excellent Education, 2011, p. 2). One such technology support is the computer-assisted instruction (CAI) approach, which provides engaging, real-life tasks with pictures,

visuals and video demonstrations in order to help students make connections and construct personal, relevant meanings (Echevarria, Vogt, & Short, 2013). These concepts are found in the sheltered instruction approach where language and academic grade-level content are developed simultaneously. Echevarria, Vogt, and Short (2013) cited the theoretical underpinnings of the model as language acquisition enhanced through meaningful use and interaction. Students developed their language processes interdependently with lessons that incorporate activities that integrate those skills. This approach can also be applied to mathematics, with heavy emphasis on building background knowledge and vocabulary.

Constructivists argued that the learner must construct his or her own understanding, combining the new with the old, and the teacher "does not give up his or her role as a guide but this leadership takes the form of encouraging and orienting the students' constructive effort rather than curtailing their autonomy by presenting ready-made results" (Von Glasersfeld, 2003, p. 1). For the ELL student, understanding is hampered by the language barrier, but CAI was found to be helpful in this language-learning process by providing connections from language to realia (Buxton, 1999; Janzen, 2008; Rodriguez, 2001). The CAI programs were designed to quickly assess the skill level of the student, administer the appropriate instruction and practice, and then give immediate feedback to the student (Shoppek & Tulis, 2010). The National Council of Teachers of Mathematics (Leinwald, S., Huinker, D., & Brahier, D., 2014) cites technology as one of their Principles for School Mathematics and claimed it an essential part of teaching and learning mathematics; one that enhances student learning.

Problem Statement

The gap in mathematics achievement by differing population groups prompted educators to seek out help for their underachieving students. Historically, the gap persists between ELL students and non-ELL students. Supplementary programs delivered in the form of CAI have gained widespread use as mediation tools for this subpopulation. Genesee (2006) and others cited lack of research available specifically concerning the effects of CAI on ELL mathematics achievement. This study helped to fill that void in research.

Purpose Statement

Mediation tools, such as CAI, have been found to be effective for some students (Genesee, 2006). The different components contained in CAI Mathematics programs promoted student achievement by following research-based sheltered instruction tenets. Some examples, such as providing relevant and engaging tasks, providing visuals, targeting vocabulary, providing adaptive tasks, and opportunity for practice with effective feedback are built into many CAI programs. The purpose of this study was to examine the impact of CAI supplemental implementation on student achievement as measured by MAPS assessment data, and to determine if the CAI supplement was more beneficial than TI alone. This study compared students who used CAI as a supplement to their mathematics instruction to those students who only received regular mathematics instruction without the CAI supplement. The two CAI mathematics programs used at the elementary level during the study were SuccessMaker and Compass Odyssey. Research on the impact of CAI and its effect on different populations of students was considered limited and in need of further study. This research will assist educators in identifying appropriate use of such programs, and provide educational administrators with

additional information to guide decisions about technology adoptions and purchasing to enhance the educational achievement of their students.

Significance of the Study

This study contributed to the growing body of literature concerning ELL best practices instruction in mathematics using CAI supplemental programs and their effect on student achievement. The National Mathematics Advisory Panel from the United States Department of Education (USDOE) (2008) recommended more research on issues related to software use in the areas of implementation according to developer's guidelines, integration into the curriculum, and the use of software to replace or supplement other instruction. In addition, they called for randomized control designs or methodologically rigorous quasi-experimental designs, which involved adequate statistical power. There are numerous studies that have reported upon CAI at all education levels, including kindergarten through university (Christmann, Lucking, & Badgett, 1997). However, there are a very limited number of studies that address the effects of CAI supplemental programs with ELL student populations at the upper elementary level. More research is needed to study CAI interventions through the lens of sheltered instruction, which is considered best practices for ELL students.

SuccessMaker and Compass Odyssey are both CAI programs with literacy and math components. Both programs have computer-adaptive assessments and placement tests, individually customized lessons and practice, step-by-step tutorials, interactive and engaging student experiences, gaming and puzzle tasks, remediation, reinforcement or enrichment learning paths. Both programs are recommended as a supplement to core instruction, which is the Everyday Math curriculum (DiLeo, 2007).

The goal of this study was to examine the growth in achievement for ELL students. If student achievement for ELLs is positively affected with the additional CAI software, then this practice should be expanded across the district. This study can also help guide our future program evaluation efforts and purchasing recommendations with regard to the district ESL program.

Research Questions

The following research questions were addressed in this study:

Question 1: What was the effect of CAI on mathematics achievement scores for third and fourth grade students?

Question 2: Was there a significant difference in the mathematics achievement of third and fourth grade regular education (non-ELL) students who experienced traditional instruction supplemented with computer-assisted instruction?

Question 3: Was there a significant difference in the mathematics achievement of third and fourth grade ELL students who experienced traditional instruction supplemented with computer-assisted instruction?

Research Hypotheses

Based on the research questions, the following hypotheses were framed to evaluate the data:

H_1: There is a significant difference in the mathematics achievement of third and fourth grade students who experienced traditional instruction supplemented with CAI.

H_2: There is a significant difference in the mathematics achievement of third and fourth grade regular education (non-ELL) students who experienced traditional instruction supplemented with computer-assisted instruction.

H_3: There is a significant difference in the mathematics achievement of third and fourth

grade ELL students who experienced traditional instruction supplemented with computer-

assisted instruction.

Identification of Variables

- Name
- Grade
- ELL v Non-ELL
- CAI v Traditional

The results of this study provided researchers, teachers, parents, administrators, school

board members and legislators with information about how supplemental computer-assisted

instruction in mathematics can have an impact on the education of ELL and non-ELL students in

grades three and four through the lens of sheltered instruction. This study also informed about

how successful CAI is with ELL students, non-ELL students, female and male students, and

third and fourth grade students as a component of the sheltered instruction model. Since there are

several schools implementing CAI as a supplemental resource over multiple years, we analyzed

the effectiveness of this tool on different groups of students. This information added to the

evidence of best practice and equipped school leaders with current, pertinent information to aid

in the decision-making process to further improve mathematics education.

Assumptions and Limitations

The following are limitations of current research and address changes for future research:

- Time on task and minutes of use vary greatly across studies. This variable is not

  consistently taken into account by many studies.

- The results from Odyssey Math and SuccessMaker Math cannot be generalized to other

  CAI components or to the Literacy portions of these components. These programs have

been vetted by USDOE and the What Works Clearinghouse (WWC) as proven and

successful with general populations of students. However, there are very few studies

examining their use with ELL populations of students.

- The results of this study only apply to third and fourth grades and not to other grades.
  Other studies generalize findings too broadly to K-1-2 and middle grades.

- SuccessMaker and Odyssey Math are used as a supplement to the instruction. Findings of
  this study only pertain as a supplement to the curriculum, not as a replacement of core
  classroom instruction, as they have been in other studies.

- Experimental research with random assignment to the treatment or control groups is the
  gold standard for statistical research. This study is a quasi-experimental, ex post facto
  study at only one school district in Arkansas.

- This study only examines student achievement as detected by the NWEA MAP for
  mathematics.

Definition of Terms and Variables

To encourage clarity for the reader, the following definitions of terms and variables are

offered:

1. <u>Name</u> refers to the student name upon registration reported by APSCN (Arkansas
   Public School Computer Network).

2. <u>Grade</u> refers to the school grade as reported by APSCN.

3. <u>Computer-assisted Instruction (CAI)</u> refers to the supplemental computer-based
   programs available in selected elementary schools, such as SuccessMaker and
   Compass Odyssey. CAI is designed to offer dynamic assessment, direct

instruction and immediate feedback interactively in an attempt to improve achievement.

4. Traditional Instruction (TI) refers to the Everyday Math Curriculum adopted district-wide for core content curriculum. This is implemented at all elementary schools in the district, and used with all subpopulations of students.

5. English Language Learner (ELL) describes students enrolled in the English as a Second Language (ESL) Program.

6. Non-ELL refers to students who are not enrolled in the ESOL program.

7. NWEA MAP refers to the Measure of Academic Progress (MAP) assessment from the Northwest Evaluation Association (NWEA), which is given to all students in grades 3-9 and administered in fall, winter and spring in the subjects of Mathematics, Reading and Science.

8. Sheltered Instruction (SI) describes an instructional approach specifically designed for ELL students that contains various components to help ELL students synthesize new information by building context. Sheltered Instruction makes grade-level core content accessible to ELLs, while building vocabulary and other English skills. Sheltered Instruction Observation Protocol (SIOP) is a specific version of SI.

9. LEP describes Limited English Proficient students who may or may not be enrolled in the ESOL program.

10. Combined Population is a group of students containing all students who took a given assessment, usually referring to state Benchmark assessments prior to the

2013-2014 school years.

11. <u>ESEA</u> refers to the Elementary and Secondary Education Act.

12. <u>ADE</u> refers to the Arkansas Department of Education.

13. <u>PISA</u> describes the Programme for International Student Assessment that compares math and literacy performance for students around the world every three years.

14. <u>CCSS</u> refers to Common Core State Standards that Arkansas and many other states have adopted. The benefits of these standards are increased rigor and depth, with more difficult content introduced at earlier grades.

15. <u>TIMMS</u> Trends in International Mathematics and Science Study (TIMSS) is a study collecting data for the National Center for Education Statistics on the mathematics and science achievement of fourth and eighth grade students in the United States and compares the results to that of students in other countries. TIMMS data is collected every four years, with the next slated for 2015.

16. <u>Realia</u> refers to real-life objects used by teachers to connect student thinking to knowledge and language.

CHAPTER 2: LITERATURE REVIEW

Introduction

This review synthesized the research from five areas of mathematics education: a brief summary of major initiatives and reforms in math education, theoretical learning ideas and how they connect with computer-assisted math interventions like SuccessMaker and Odyssey, sheltered instruction and best instruction practices for all students, evolution of technology with CAI, and student achievement. Clements and Sarama (2007) recognized mathematics learning as a complex process based on students' innate competencies, students' experiences, and thinking processes. Although there are other factors beyond the scope of this study affecting the mathematics achievement of our ELL students, such as poverty, culture and prior learning, this literature review focused on the research and effects of supplemental computer-assisted interventions.

Initiatives in Mathematics Education

Mathematics Education efforts in K-12 education and particularly in the elementary grades have been through various stages of reform from the "new math" era of the 1970s to the current Common Core movement of today. The evolution of these reform efforts is described briefly to provide historical perspective on the current state of mathematics education. This section will provide a brief overview of mathematics curriculum and instruction over the course of the last 60 years.

Mathematics education in the US has undergone several transformations. The need for factory laborers in the early 20th century required an educational emphasis on basic skills. Schools needed to produce a workforce capable of performing arithmetic accurately. This

changed when Sputnik was launched by the Soviet Union in 1957, and with it the new concern that the US was falling behind in curriculum for math and science. Burris (2005) called this the beginning of the space race between the US and USSR, but it was also the beginning of the "new math" movement of the 1960s. The design of math curricula in the "new math" era was focused on abstract concepts and notations. This premise was a mismatch with cognitive development. Thus, the movement never fulfilled the promise of increasing America's mathematical expertise. The failure of the "new math" movement brought about the trend of Back to Basics in the late 1970s and early 1980s, which emphasized arithmetic computation and rote memorization of algorithms and basic arithmetic facts (Burris, 2005).

The 1980 National Council of Teachers of Mathematics (NCTM) report, *An Agenda for Action,* was considered a call for change in math education for the 1980s. NCTM recommended that problem-solving be the focus of math curriculum. They also recommended students be given access to calculators and computers at all grade levels, be required to complete more math courses and be provided a wider range of curriculum governed by stringent standards (Hill, 1980).

In 1983, A *Nation at Risk* was released by a number of commissioners appointed by then U. S. Secretary of Education Terrell Bell. The report cited the "rising tide of mediocrity" (p. 113) in American education as being an "act of war" (p. 113) if perpetrated by a foreign authority. Bell (1983) sounded the alarm, citing the US, "once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world" (p. 113). The curricular offerings of the high schools across the country were great, but very few students were taking advantage of academically rigorous courses like calculus. There

was a call for regular academic achievement tests to evaluate student progress, and also increased teacher preparation reform, especially in math and science. This report not only caught the attention of math educators, but also the general public, and caused a widespread public perception that something was seriously wrong with our education system. Hunt (2008) claimed educators have felt the need to respond to the criticism of schools by legislators, business interests and the general public. In 1989, NCTM expanded the work of the early 1980s to include more specific guidelines on teaching and learning mathematics in the K-12 school. The *NCTM Curriculum and Evaluation Standards for School Mathematics* called for appropriate use of calculators, student-centered discovery learning, and real-world problems.

In the late 1990s, educators called for radical changes from the predominant algorithmic methods of teaching arithmetic and fractions in the elementary grades to more conceptual approaches. The National Science Foundation (NSF, 1996) called for reform in defining the components of effective, standards-based education. They called for meaningful curriculum related to real-world situations, lessons with more hands-on activities and cooperative group problem-solving with technology integrated to make the learning easier, more comprehensive and more lasting.

Theoretical Framework

One theory underpinning the narrative of the NCTM standards was the advancement of constructivist learning theories in recommendations for changes in teaching methods (Kim, 2005). This was due in part to cognitive research on how students learn. Bruner (1961) asserted that learning is an active process in which learners construct new ideas or concepts based upon their current knowledge. He further argued that the learner selects and transforms information,

constructs hypotheses, and makes decisions, relying on a cognitive structure to do so.   Bruner and Tajfel (1961) posited several roles for the classroom teacher to improve student learning based on constructivist theories. They contended that the teacher should try and encourage students to discover or construct learning for themselves. They also suggested active question and answering between the student and teacher, with redirection by the teacher. The teacher should guide the student to developmentally appropriate curriculum, and present it in a way the student can understand, while challenging the student to learn more. Curriculum should be organized in a spiral manner so that the student continually builds upon what he or she has already learned. Additionally, Bruner (1961) asserted that a theory of instruction should address four major aspects: (1) predisposition towards learning, (2) the ways in which a body of knowledge can be structured so that it can be most readily grasped by the learner, (3) the most effective sequences in which to present material, and (4) the nature and pacing of rewards and punishments.

   Mathematics educators also gleaned support for constructivist teaching from the writings of Piaget (stages of development) and Vygotsky (zone of proximal development), which both advocated child-centered, cooperative learning. Piaget's ideas stemmed primarily from his one-on-one interaction with children. Piaget's work was foundational for considering the role of connections, whether implicit or explicit, between previous and new understandings (Hiebert & Carpenter, 1992). Additionally, the social context was considered critical in determining the types of connections that would influence student learning within classrooms (Kaun, 2009). The social context includes both peer and student-teacher interactions as well as the role of mediating tools such as concrete objects, symbols and gestures in real and virtual personalized learning

environments. Cobb (2011) builds on the work of Ernst Von Glasersfeld and recommended sustained engagement over time and learning by combining conceptual activity and sensory-motor action.

Constructivism and Computer-Assisted Instructional Interventions

Research on the effects of CAI on student learning in mathematics was varied and the results were mixed. Furthermore, the connection between theories of constructivism and CAI are limited primarily to qualitative studies that have analyzed individual students' interpretations and progress through computer-based simulated mathematics activities that were closely monitored by the teacher and/or researcher. Clements, Batista, and Sarama (2001) found significant results for a geometry curriculum called Logo; however, their research was based on only a few students over the course of one school year. Their research was also for a comprehensive, stand-alone curriculum and not a supplemental intervention. Further research is needed for supplemental interventions, versus stand-alone replacements of core curriculum. Past research has shown that integrating technology can more effectively promote constructivist goals, such as higher-order thinking skills and motivation to learn (Rosen, 2009). Findings of this study included a significant impact of an interactive program on motivation of students to learn science. However, most initiatives use technology as a substitute for parts of traditional instruction, instead of promoting innovative, technology-rich activities as a comprehensive change in teaching and learning (Weston & Bain, 2010). Clements and Sarama (2007) also found computer manipulatives help with students' mathematical knowledge. This study focused manipulatives the students used in problem-solving. In a more recent study, Clements, Sarama, Spitler, Lange, and Wolfe (2011) found that children in the treatment group using the Building

Blocks curriculum learned more mathematics than children in the control group (effect size, g =

.72). In this study, teachers used the Building Blocks intervention and were provided

professional development. The Research-based Elementary Math Assessment (REMA), which

measures core mathematical abilities of preschool children, was given as a pretest and posttest

using the individual interview format. Clements, Sarama, Spitler, Lange, and Wolfe (2011)

reported that the learning gains made by the Building Blocks group relative to the control group

were, in descending order, items involving object counting and counting strategies, verbal

counting, comparing number and sequencing, recognition of number, composition of number,

and arithmetic word problems. The researchers also cited a need for further studies to evaluate

the effects of curriculum-based interventions such as this one.

Some have argued that using computer-assisted instruction in the classroom made the

learners experience more authentic (Moersch, 1998), more interactive, and more efficient (Li &

Ma, 2010). Using a meta-analysis of 46 primary studies, Li and Ma (2010) found statistically

significant positive results for computer technology and its effects on mathematics learning. In

addition, the computer technology had greater effects when paired with constructivist teaching

strategies. The study also found that lower achieving and at-risk students, such as special needs

students, achieved more than regular education students (Li & Ma, 2010). The study surmised

that computer technology is an essential, necessary tool in good teaching and learning. And, that

the types of computer technology used (tools, tutorials, manipulatives, etc.) were all found to be

effective. Two items of importance in this study were the amount of time the interventions lasted

and the lack of information on how computer technology affects the mathematics achievement of

ELL students. The majority of interventions only lasted for six months, which calls into question

whether the novelty issue actually caused the improvement. This study did not accomplish any research on effects for ELL students' mathematics achievement or longitudinal research for computer technology and its effects on mathematics achievement.

Evolution of CAI Technology

The first computer-assisted instruction model was developed at Stanford University in 1963 (Suppes & Atkinson, 1963). This program contained math and reading components and was based on the mastery learning model. Bloom (1968) described the differences in traditional instruction and mastery learning as increasing the quality of instruction and the amount of time available in order to help the majority of students achieve a mastery level of knowledge. Papert (1980) also advocated integrating computers into the learning process. This idea became possible with the advent of the microcomputer in 1975. By the time supercomputers and the forerunner of the internet came along in the 1980s, computers were inexpensive enough for school districts to purchase. The 1980s also brought about the transformation educational programs such as CD ROMs that led to more adaptable tutoring systems.

Early computer-assisted instruction programs were drill and practice-based. The programs in use today are more intelligent tutoring systems that use a basis of information from psychologists. They are more tailored to the needs of the individual student and are created with the constructivist model of learning. Calik, Ayas, and Coll (2010) defined the four-step constructivist model used in the present work as: (1) eliciting students' preexisting ideas, (2) focusing on the target concept, (3) challenging students' ideas, and (4) applying newly constructed ideas to similar situations. This is an adaptation of the Generative Learning Model (Cosgrove & Osborne, 1985; Osborne & Wittrock, 1983). Wittrock (1974) said the learner is not

a passive recipient of information; rather, she or he is an active participant in the learning process, working to construct a meaningful understanding of information found in the environment. Wittrock (1974) also emphasized the importance of asking the learner to generate his or her own meaning.

Piaget believed that students must construct their own knowledge; they must make sense of things through their own experience with meaningful activities. Teaching skills in isolation will not work. Every acquisition of accommodation becomes material for assimilation, but assimilation always resists new accommodations (Piaget, 1955). However, Piaget did not emphasize the social nature of the learning process like Vygotsky. What children can accomplish with the support of adults and peers might be even more indicative of their mental development than what they can do alone (Vygotsky, 1978). The new CAI programs were created with these things in mind.

Figure 1 shows a screen capture of the internal thinking problem-solving steps that goes with a guided practice problem in the Odyssey program. In the video, the CAI virtual tutor presents the problem, then verbalizes and illustrates each step in the problem-solving process. There are also connections made between skills, such as addition fractions and multiplying fractions. Finally, a solution is checked for reasonability. The student would experience this program as a supplement to the core curriculum, not as an introduction, and it would allow students to experience more time in the guided practice stage, if necessary.
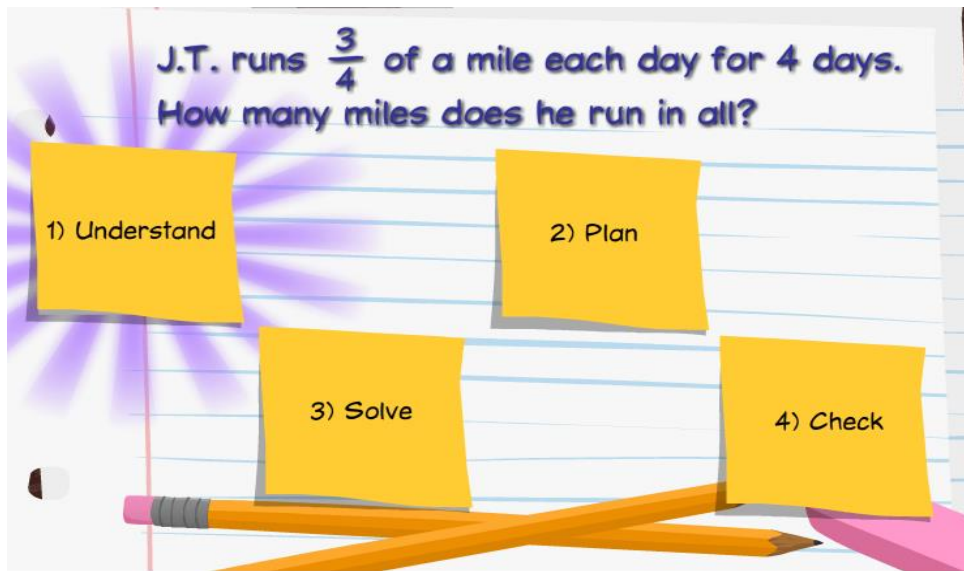
Figure 1. The virtual tutor verbalizes internal thinking of problem-solving steps with a guided practice problem.

Pedagogical Learning Theories and CAI

Vygotsky's theories contained the idea of mediation tools, and with these tools used in a social setting rich in language, new learning is taking place. Vygotsky (1979) asserted that new learning must be processed in a social context, then internally through self-talk. Implications for CAI include the program acting as a substitute for additional one-on-one feedback time with the teacher. Many CAI programs have language components requiring the student to speak aloud important vocabulary and concepts. The CAI programs also tailor instruction in response to the question and answer responses given by the student. Vygotsky (1979) also asserted the zone of proximal development (ZPD), which is the difference between what the child can accomplish on individual tasks, and what the child can accomplish with the help of others. It is in this zone that optimal learning occurs.

By completing a pre-assessment of the student's skills, CAI programs were designed to present lessons targeting the child's ZPD. Students benefited from mathematics tasks with high cognitive demands, including dialogue and guided-feedback (Hsu, 2013). Von Glasersfeld (1989) suggested the importance of giving children direction and skill sets, but allowing them to find their way. The CAI programs were designed to respond to the child's correct or incorrect answers, providing praise and advancement or additional tutoring and review accordingly.

Furner, Yahya, and Duffy (2005) recommended taking Internet field trips and using mathematics software to aid in learning. They also recommended emphasis on vocabulary by using realia, demonstration and by creating word bank charts for classroom display. These recommendations are included in the sheltered instruction approach. Research also provided support for explicitly teaching a variety of strategies for learning. Echevarria, Vogt, and Short (2012) emphasized the importance for ELLs to learn and practice a variety of learning strategies in both language and content instruction. One example of this that applies to mathematics is the use of graphic organizers. August and Shanahan (2010) argued that providing scaffolding in the form of visual representation of language is a common strategy that increases the chances that students who are unfamiliar with English will understand lessons sufficiently. CAI programs included in this study all had the emphasis on vocabulary and use of graphic organizers to aid student learning.

DuFour (2008) recommended teachers participate in close, frequent monitoring of individual student learning. This is based on a study from Daniels and Arapostathis (2005) that reported the frequency that students discussed classroom curriculum and activities with their friends outside the school day. Only 20% of the students surveyed worked on projects and

assignments outside of class time. Fleischman and Heppern (2009) recommended a personalized, orderly learning environment where there is an atmosphere of support for all students. They found that when students become disengaged and detached, they become defiant, sometimes violent and spiral into the dropout oblivion. DiMartino and Clarke (2008) claimed increased use of technology helped students gain access to more curricula and also helped teachers to manage large groups of students, each struggling with different aspects of challenging tasks.

Fleishman and Heppen (2009) also encouraged a support system to assist students with low academic skills, particularly in the areas of math and literacy. They cited scores from the NAEP (National Assessment of Educational Progress), where a significant number of students enter high school ill-prepared for academic success. The weakness in literacy and math is particularly troubling; therefore, comprehensive reform models usually have some kind of component to address these issues. Computer-assisted instruction can be a component of a more individualized educational experience, mimicking the one-on-one assistance impossible to achieve with today's class sizes.

Fisher (2003) gave guidelines for effective interventions. These include the teacher as a critical role and the difference-maker, assessments that are useful and relevant, and consistent and authentic opportunities for learning vocabulary, reading and writing. Computer-assisted instruction proved helpful for the assessment and reinforcing academic vocabulary pieces of the complex teaching puzzle. In a research study completed in 2005, Tran found students who participated in a web-based math program performed significantly better than those students who did not. The What Works Clearinghouse also gave their highest rating to the same intervention.

This literacy-based approach also applies to mathematics instruction interventions. Students should always be able to explain their answers in both written and verbal formats. Whatever the subject, teachers should always be attentive to point-in-time remediation moments, or teachable moments. Computer programs, no matter how complex, will never take the place of an attentive teacher.

Core and Supplemental Mathematics Curriculum

Odyssey Math, a web-based K-12 mathematics curriculum and assessment tool, was designed to allow for differentiated instruction and data-driven decision-making. What Works Clearinghouse (2009) stated that there was an online component with game-like instruction and practice, assessments aligned with standards, and data that allows for individualized plans for students. This system was marketed as a stand-alone curriculum or as an intervention program. However, the local use for the study was intervention-based. The WWC report (2009) stated the study focus was primarily on the relationship between the Odyssey Math usage for the treatment group and student achievement. The author also examined outcome differences in the treatment and control groups. In the study, the improvement index was 17, with a small extent of evidence and potentially positive effectiveness rating. WWC defined the improvement index as the expected change in percentile rank for an average comparison group student if the student had received the intervention. It was measured as the percentile difference between the intervention-group and the comparison-group mean using the comparison group distribution. The extent of evidence was reported as small, which means that there was only one study, one school, or findings based on a total sample size of less than 360 students. The rating of effectiveness contained four factors: the quality of the research on the intervention, the statistical significance

of the research findings, the size of the differences between participants in the intervention and comparison groups, and the consistency in findings across studies (WWC, 2009).

Echevarria, Vogt, and Short (2013) called for key vocabulary to be emphasized, and believed that students should be immersed in words in different ways that aid them in recognizing and using them. They cited a Saville-Troke (1984) study that highlighted a close relationship between vocabulary knowledge and academic achievement. This emphasis on vocabulary is a hallmark of sheltered instruction techniques and is an integral part of building background knowledge for ELL students.
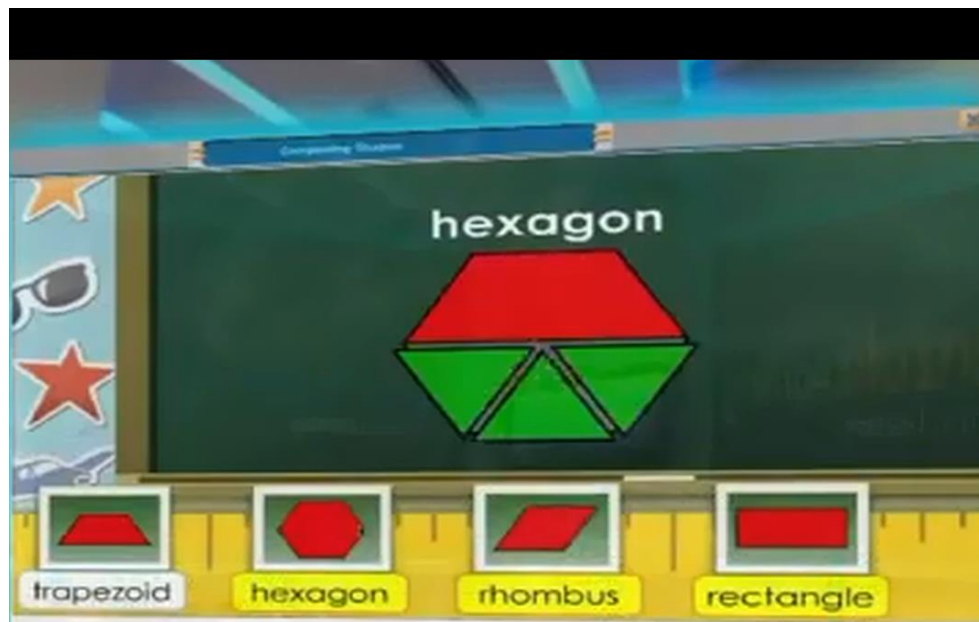
Figure 2. Vocabulary is paired with video and pictures of shapes to help the student connect the academic language with the visual.

Odyssey also features direct instruction with connections made between past learning and new learning. Rumelhart (1980) stated that new information must be integrated with what the

learner already knows. Many ELL students do not automatically make these connections, and all students benefit from explicit instruction by the teacher pointing out what the student already knows and connecting that to new learning (Tierney & Pearson, 1994). Echevarria, Vogt, and Short (2004) stated that this process of connecting old and new information was particularly important for ELL students because they receive so much input through new language. Figure 3 illustrates connection addition (old information) to multiplication (new information) of fractions through a matching game. The program also gives students guided practice with constant feedback along the way.
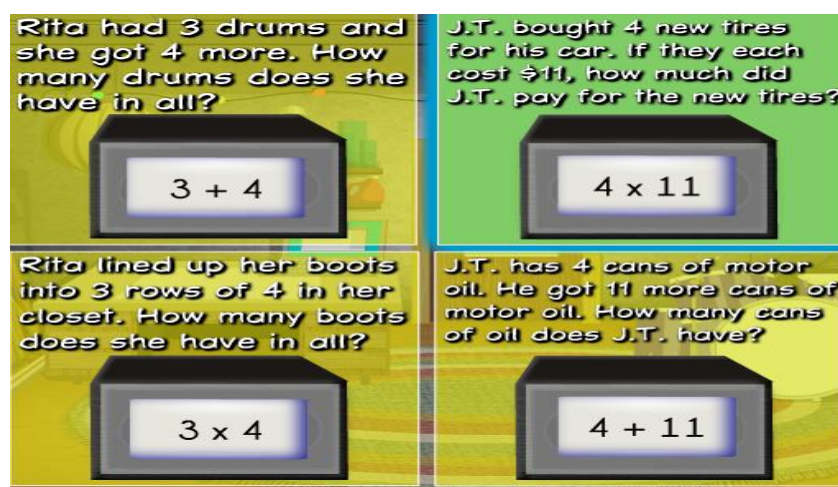
Figure 3. Students see and hear verbal and written prompts connecting addition and multiplication to solve problems.

SuccessMaker Math is similar to Odyssey Math in format. It also has the formative assessment component and is individually tailored to the student's needs. It is described as a digitally driven K-8 learning experience focused on fundamental mathematics concepts (Gatti, 2010). The instruction is described as differentiated with mathematics content that combines

instruction in fundamental skills with development of higher-order thinking strategies. The system has a brief initial placement assessment to target the student's comfortable learning level, and then advances his or her learning through educational games and practice. According to Gatti and Petrochenkov (2010), the SuccessMaker participants significantly outperformed their control group peers in both areas of achievement and academic attitude. The difference in achievement was greater in the third grade than in the seventh grade groups. This supports earlier statements that greater impact can be exacted in earlier, rather than later grades.

Everyday Math was used as the traditional instruction component for all students in the study. According to WWC (2010), Everyday Math reported an improvement index of 11, with potentially positive effects and a small extent of evidence. The study focused on grades three, four and five. According to WWC (2010), Everyday Math, published by Wright Group/McGraw-Hill, was described as a core curriculum for students in pre-kindergarten through grade six. At each grade level, the curriculum provided students with multiple opportunities to learn concepts and practice skills, presented in a spiral curriculum. Across grade levels, concepts are reviewed and extended in varying instructional contexts. The distinguishing features of the program are reported as focus on real-life problem solving, student communication of mathematical thinking, and appropriate use of technology. This core curriculum also emphasized the varying different types of instruction (including collaborative learning), using several methods for skills practice, and nurturing parent involvement in student learning (WWC, 2010).

History of Computer-Assisted Instruction and Link to Achievement

As early as the 1960s, Suppes and Morningstar (1969) studied two computer-assisted instructional programs that consisted of a daily dose of drill and practice of mathematics skills. Although this study reported mixed results, the authors verified that the computer-based program is a good way of maintaining consistent drill and practice quality control in large numbers of classrooms and schools. They also found large student gains in short amounts of time, especially in poor areas (Suppes & Morningstar, 1969). Reviews of these evaluation studies generally supported the effectiveness of computer-based programs as a supplement to traditional instruction in elementary schools. Vinsonhaler and Bass (1972) summarized results from 10 studies of computer drill and practice. Results indicate a considerable benefit for computer-augmented instruction. Elementary school children who received computer-assisted instruction generally showed performance gains of 1-8 months over children who received only traditional instruction. Edwards, Norton, Taylor, Weiss, and Dusseldorp (1975) also concluded that traditional instruction, augmented by computer-based teaching, was more effective than traditional instruction alone. Jamison, Suppes, and Wells (1974) also concluded that computer-assisted instruction was effective as a supplement to regular instruction at the elementary school level. Hartley's (1977) research synthesis showed that computer-assisted instruction was one of the most effective ways of teaching mathematics at the elementary and secondary levels. Hartley was the first to use meta-analysis to evaluate CAI. Although these drill and practice programs were relatively successful, the real push for technology in the classroom came with the increasing availability and use of microcomputers.

Levine (2001) reported that by 1983, 53% of American schools and 85% of high schools had at least one computer. Hasselbring (1986) found equal or better achievement in less time with CAI, improvement in student attitude toward learning with CAI, and that CAI worked best as a supplement to core curriculum. In another meta-analysis, Kulik (1994) found that students learned more in less time with CAI. Additionally, students liked their classes more if they contained a CAI component, and showed a more positive attitude towards computers with CAI.

Christmann and Badgett (2003) found the academic achievement of elementary students who received traditional instruction, supplemented with computer-assisted instruction, accomplished higher academic achievement than traditional instruction alone. In a more recent study, Qing and Xin (2010) examined the impact of computer technology on mathematics education in a meta-analysis, and found significant positive effects. They also found better results at the elementary level than secondary and better results when paired with a constructivist teaching approach. Using technology in school settings where teachers practiced a constructivist approach to teaching showed larger effects on mathematics achievement than using technology in school settings where teachers practiced a traditional approach to teaching (Qing & Xin, 2010).

> This implies that technology may work better in a certain type of learning environment. This is exciting news to us in that technology does require a context to intervene with the learning of mathematics. With available data, we can only test between the constructivist approach and the traditional approach to teaching. The result indicates that a constructivist approach facilitates technology to impact the learning of mathematics. It highlights the importance of the contextual consideration of technology in promoting the learning of mathematics. p. 234.

Clements, Sarama, Spitler, Lange, and Wolfe (2011) studied LEP students and the effectiveness of a Pre-K curriculum called Building Blocks with technology components

mentioned earlier. They found significant effects when comparing the Building Blocks group to the control group. The Building Blocks group outperformed the comparison group with an effect size of 0.72. This study was one of the few found to report results by LEP status, and cited that LEP status was not a predictor of mathematics achievement. This study is important because the technology component was only a supplement to the curriculum, which is the case in this study. However, the study only tested Pre-K students and it is not generalizable to upper elementary. In fact, there was no study found that specifically examined mathematics achievement of upper elementary ELL students using CAI as a supplement to core curriculum in a gold-standard randomized trial for an extended period of time. This fact highlights the need for this study to further examine the issue.

Mathematics Achievement

There are several achievement assessments, both national and state, to be examined for this study. It is important to look at different kinds of assessments, such as norm-referenced (NRT), criterion-referenced (CRT), and measures of academic progress and growth. The last kind of assessment is important because it gives us formative information to drive instruction and it also gives us snapshots of achievement for each student across the span of a school year. Locally, the MAP assessment was used to drive instruction and measure growth.

NAEP is an assessment taken by randomly selected fourth and eighth grade students across the United States. In 2013, higher percentages of students scored in the acceptable proficient range, than in years past. The average NAEP mathematics scale score for fourth graders was 242, an increase of two points from 2009 to 2013. However, during the same time frame, the scale score for ELLs rose only one point and stagnated at 219. This pronounced gap

between the average score of all students and ELL students of more than 20 points for fourth grade was consistent across more than two decades (NCES, 2011). On the 2009 NAEP, forty-three percent of ELL students in fourth grade scored Below Basic, but only 16% of the non-ELL students did. 41% of non-ELLs scored at proficient and advanced levels, but only 12% of ELL students attained that standard (Echevarria, Vogt, & Short, 2013).

Another notable assessment piece is the Programme for International Student Assessment (PISA). Although this is not an elementary assessment, the results report mathematics performance for the United States relative to the rest of the world. There are 34 countries participating in PISA, and the US ranked below average at 26th in mathematics (PISA, 2012). We also showed a greater than average share (25.8%) of low achieving math students and a smaller than average share (8.8%) of higher achieving math students (PISA, 2012). Over the course of the last three PISA assessments, United States math achievement scores stagnated, but the adoption of Common Core State Standards (CCSS) is expected to improve the US ranking in future years (PISA, 2012).

The Trends in International Mathematics and Science Study (TIMMS) provides reliable and timely data on the mathematics and science achievement of US fourth and eighth grade students compared to that of students in other countries (TIMMS, 2014). Unlike PISA, this assessment in math, literacy and science was given every four years and the data is reported by the National Center for Educational Statistics. The fourth grade data from 2011 showed mathematics achievement in a better light than the PISA study. US fourth grade performance in mathematics averaged a 541 score, which is above the 500 average of all countries. However, the 541 US average score was 65 points below the Singapore average of 606 (TIMMS, 2011). For

fourth grade, the US students performed relatively well, with only 8 countries in the study above that average, including Singapore, China and Japan (TIMMS, 2011). Over the last 16 years, fourth grade mathematics scores jumped 23 points and 12 points in the last 4 years. Perhaps this is due to the reform movements in elementary mathematics.

Sheltered Instruction

Sheltered Instruction (SI) is a framework for planning and delivering instruction in content areas such as science, history, and mathematics to limited-English proficient students. This research included here details the hallmarks of SI because they run parallel to components in CAI. Echevarria, Vogt and Short (2012) listed the goal of SI as helping teachers integrate academic language development into their lessons, allowing students to learn and practice English as it is used in the context of school, including the vocabulary used in textbooks and lectures in each academic discipline. Using this planning framework, teachers modified the way they taught so that the language they use to explain concepts and information is comprehensible to these students. The sheltered instruction planning and observation framework covers eight areas of instruction: preparation, building background, comprehensible input, strategies, interaction, practice and application, lesson delivery, review and assessment (Echevarria, Vogt, & Short, 2012). In most cases, teachers received professional development before using it to modify their lessons (WWC, 2012). Many of the tenets of the sheltered instruction model are reinforced by CAI efforts, such as vocabulary emphasis and building background knowledge, practice and application, lesson delivery and review and assessment. Bailey (2007) claimed that the academic language demands of school pertain to mathematics no less than other subjects. Bailey (2007) found that students made gains on mathematical achievement more quickly and at a greater rate than other disciplines. She also recommended new language input be accomplished

with demonstrations, pictures, and manipulatives for both the focal math concept and key math vocabulary (Bailey, 2007). These are all part of the CAI programs currently available in the district.

McTighe and O'Connor (2005) recommended differentiating instruction specific to the individual student needs, like the use of formative and summative assessments and providing pertinent feedback early and often. Tomlinson and Imbeau (2012) defined the differentiated classroom as heterogeneously grouped and designed to attend to learner variance. The learner is at the center of teaching and learning, and his or her needs are met on an individualized basis. Tomlinson (1999, 2003, 2010) and Gavin and Moylan (2012) believed the core of differentiation revolves around the modification of curriculum content, process and product throughout each lesson. Specifically, they called for providing additional support for struggling learners at all points during the lesson, like vocabulary and process reminders to connect current material to past learning. Short, Fidelman and Louguit (2012) completed a study on SI and student achievement. They specifically studied the Sheltered Instruction Observation Protocol (SIOP) model as a professional development framework in middle and high schools. The teachers with SIOP training incorporated more elements of sheltered instruction than those without SIOP. The researchers claimed that the instruction in the classroom was different, and therefore differences in student achievement could be related to teacher training and the SIOP model. Overall, the treatment students performed better on their language assessments, even though the professional development was primarily given to math, science and social studies teachers. By year two of the study, the treatment group scores were statistically significantly higher and the achievement gap

closed. Researchers also recommended two or more years of professional development before a high level of implementation is reached (Short, Fidelman, & Louguit, 2012).

Personalized, differentiated learning environments have been found to be consistent with features of CAI. The programs have been found to quickly assess the skill level of the student, administer the appropriate instruction and practice, and then give immediate feedback to the student (Shoppek & Tulis, 2010). CAI is especially important in mathematics because the prerequisite skills build upon one another from year to year. Table 1 summarizes the alignment and correlations between SI, CAI and theoretical and pedagogical research. SI and CAI studies cite the same theoretical and pedagogical research.

Table 1

Sheltered Instruction and CAI are both backed by the same research.

Sheltered Instruction	CAI
Ongoing Assessment	Pre/Post Test, Formative and Summative Assess
Clear Content Objectives	Clear Content Objectives
Key Vocabulary Focus	Key Vocabulary Focus
Clear Explanation of Key Concepts	Explicit Instruction
Scaffolding Techniques	Graphic Organizers, Modeling, Structure
Engaging, Meaningful Activities	Real-World Applications Gaming/Graphics
Higher-Order Thinking Skills Promoted	Integration of Ideas, Leveled Questions, Spiral Curriculum
Regular Feedback	Rewards for Correct

Building background knowledge by emphasizing key vocabulary is a significant component in sheltered instruction, and is also found in CAI programs. Vocabulary development

was found to be critical for ELLs and is strongly related to academic achievement (August & Shanahan, 2008; Biemiller, 2005; Hart & Risley, 2003; Zwiers, 2008). In these lessons, teachers emphasized words that are critical to understanding the text or material and provided a variety of ways for students to learn, remember over time, and use those words to develop a core vocabulary (Blachowicz & Fisher, 2004; Graves & Fitzgerald, 2006). Other researchers on sheltered instruction called for a comprehensive school-wide approach, including emphasis on data, intensive, ongoing staff development, supplemental tutoring and effective teaching strategies (Calderon, Slavin, & Sanchez, 2011).

Practice and application is also an important component of CAI. There have been many previous studies on programs used locally. CAI programs, Odyssey and SuccessMaker, were used to reinforce curriculum previously taught in the classroom, and to fill the skill gaps for at-risk students. Practice and application were proved to aid students in mastering a skill (Fisher & Fry, 2008; Jensen, 2008; Marzano, Pickering, & Pollock, 2001), yet ELLs needed opportunities for oral and written practice as well (Echevarria et al., 2013). Gardener (1993) advocated project-based learning assignments or those that take into consideration the different learning styles, ability levels and interests of the student. In any case, Echevarria et al. (2012) called for assignments that build foundational knowledge, supported student progress toward mastery, and advanced their proficiency levels using English. Computer-assisted instruction programs may assist with meeting these goals (Freeman & Crawford, 2008).

Student engagement during valuable class time was found to be crucial to optimizing student success (Short & Fitzsimmons, 2007; Tatum, 2008; Torgesen et al., 2007). Authors of sheltered instruction called for students to be engaged, meaning following the lesson, responding

to teacher direction and performing activities as expected 90% to 100% of the time (Echevarria

et al., 2013). Schmoker (2011) advocated paying particular attention to what (curriculum) we

teach and how (lessons) were taught. He called for increased student engagement, lower

retention rates, and access to the curriculum for all students (Schmoker, 2011). Marzano (2010)

added that student engagement is not serendipitous, but happens because of a teacher's careful

planning and artful execution of specific strategies. Student engagement is a strong feature of

computer-assisted instruction software. When asked what the teachers thought about the

SuccessMaker program, 80% of them had positive things to say. Teachers reported that their

current print supplements or past computer-based interventions could not compete with

SuccessMaker when it comes to interactivity, differentiated content, immediate feedback and

student engagement (Gatti, 2010).

The last sheltered instruction feature focuses on assessing student comprehension and

learning throughout the lesson. Echevarria et al., (2013) called for culminating or summative

assessments along with formative assessments and checks for understanding throughout the

lesson whenever teachers have the opportunity. In addition, gathering baseline data prior to

instruction in order to compare that to what students know and can do afterwards is also

recommended (Echevarria et al., 2013). According to Cohen (1985), feedback is one of the more

instructionally powerful and least understood features in instructional design. One of the

recommended ways to assess learning at the end of the lesson is to review the content and

language objectives with the class. In addition, Echevarria et al., (2013) recommended handheld

devices, vocabulary journals, and informal thumbs up or thumbs down and response boards. The

consistent message in the literature points to the teacher being attuned to knowing what students

know and can do. Next, we move to the existing research and literature surrounding the computer-aided instruction programs currently being used across the district.

Previous Research on SuccessMaker and Odyssey

SuccessMaker is the oldest computer-aided instruction program currently used, with both a Literacy and Mathematics component. The SuccessMaker program is a product of Pearson Education. Gatti (2010) stated that SuccessMaker was an instructional software program that provides elementary and middle school learners with adaptive, personalized paths to master essential reading and math concepts for grades K-8. It also provides rich data to inform instructional decision-making. This version of SuccessMaker has been available to our students since 2009 and has been used in two of the district's elementary schools since then.

Gatti Evaluation, Inc. (2010) conducted a research project on the SuccessMaker Math program in 2010 to determine if students making regular use of the program demonstrate higher math achievement as compared to students who did not use SuccessMaker Math. After adjusting for student and classroom characteristics, third, fifth and seventh grade SuccessMaker Math users statistically outperformed their comparison group peers on the Process and applications subtest by 32%. The magnitude of the difference in performance observed at all three grades was very large, 1.32, .59 and 1.01 standard deviations for third, fifth, and seventh grades respectively. The study also used qualitative data on the attitudes and opinions from teachers and students. They found that the third and fifth grade groups liked the program and the seventh grade group did not. More importantly, the data indicates clearly that diverse populations of students receiving SuccessMaker Math were successful in significantly increasing achievement (Gatti, 2010).

For all students in the Gatti (2010) study, the third grade gains reported 1.8 grade level equivalents, and fifth grade gains reported 2.9 grade level equivalents. A gain of one grade level is expected per year, so this is significantly better than expected. In addition, all subgroups of students, such as low socioeconomic groups, ELLs, and differing mathematics abilities, made significant gains. Those students with lower mathematics abilities gained more than the higher proficiency levels. This could lead to closing the achievement gap between historically low- and high-performing groups of students.

Gatti (2010) also reported teacher comments and qualitative data from the SuccessMaker program. A majority of teachers felt the initial placement and adaptive components helped students through the program effectively. The learning activities were well differentiated for their students and aligned well to their current state curriculum and educational objectives. Although most teachers made minimal use of the reporting system, the teachers overwhelmingly responded positively to the reporting system and believe it met their needs. Teachers also reported the SuccessMaker Math program was more engaging and challenging than previous printed and computer-based supplements available to them, and are helpful for ELL students and struggling readers, and an overall good educational investment (Gatti, 2010).

This study of SuccessMaker Math by Gatti (2010) was commissioned by Pearson and conducted by Gatti Evaluation, Inc. To obtain further information, an EBSCO search for SuccessMaker and Mathematics was performed with mixed results. Other studies ranged from third to fifth grade and used various methods from measures of central tendency and Chi-Square analysis, to ANOVA, ANCOVA and Multiple Regression techniques. In addition, the results range from findings that the traditional model of instruction with computer-aided instructional

supplement leads to significantly higher posttest scores to the outcome that participation in SuccessMaker was not a good predictor of success on the Texas statewide achievement test for 8th graders. However, the majority of studies and dissertations listed did find a significantly positive outcome for at least some student groups, including those involving ethnicity and disability (Lewis, 2011; Tucker, 2010; Mathis, 2010; and Gee, 2009).

     Odyssey Mathematics is another computer-assisted instructional supplement currently in use in three elementary schools. Odyssey Math is a Compass Learning product, and is a web-based mathematics curriculum for grades kindergarten through 8th grade. Like SuccessMaker, Odyssey has an embedded assessment and data management system to track student progress. The publishers claimed the program can be used as a stand-alone curriculum for mathematics, or as a supplement to the core curriculum. According to the What Works Clearinghouse (WWC) intervention report, only one of the 14 studies met WWC evidence standards with reservation, with that study showing a positive 17-point improvement index for potentially positive effects (DiLeo, 2007). The WWC computed an improvement index for each study as an average across all the studies cited. This represents the difference between the percentile rank of the treatment and control groups. Compass claimed 11 million students in over 20,000 schools use the program nationwide as of 2009. Concerns with the DiLeo study were that only fifth grade students were included in only one school district in Pennsylvania. The original study cited an ex post facto design, but the WWC claimed random assignment of subjects to classrooms. There was also only a small extent of evidence supporting the program, and no specific information about ELL students was given.

A more recent study in 2012 found no discernible effects for the program either way. This study focus was primarily on fourth grade students in schools located in Delaware, New Jersey, and Pennsylvania. The fourth graders were to participate in the program for 60 minutes per week during the entire school year. In actual practice, students spent only 38 minutes per week on the program. This shows the importance of implementation for the program is vital to achieving duplication of success gathered by other students (Wijekumar, Hitchcock, Turner, Lei, & Peck, 2009).

Initially, the SuccessMaker program implementation was examined in a preliminary study at one high-poverty elementary school in Arkansas (School A), in order to determine how the MAP testing posttests were affected by student participation in this program during the 2011-12 school year. This study occurred prior to the main study for this dissertation. The test results from the Arkansas Benchmark Examination and Iowa Test of Basic Skills were examined for the entire group of students at School A who participated in the SuccessMaker program. In addition, an examination of test scores for the ELL population of students who participated in the SuccessMaker program was completed as part of the preliminary study. Lastly, information was offered on the 2012-13 implementation progress for SuccessMaker and Odyssey programs in the district for the main study of this dissertation.

Preliminary Study Setting

School A opened in the fall of 2006 as this community's first school to serve students in Pre-K, Elementary, and Middle School. Currently, achievement status for School A for the 2012-2013 was Achieving, according to the Arkansas Department of Education (ADE) (NORMES, 2013). This means School A met achievement standards for percent tested, percent

proficient or advanced in literacy and percent proficient or advanced in math for grades 3-8 in the 2011-2012 school year.

For School A, the Limited English Proficient students (LEP) have shown growth in Math (+14%) and Literacy (+13%) over the last three years on the Benchmark assessments, but did not met status for adequate yearly progress until the ADE changed requirements in 2012 with the waiver for the Elementary and Secondary Education Act (ESEA). Gains have been made in the Economically Disadvantaged subpopulation as well, with an increase of 29 percent in Literacy and an increase of 19 percent in Math over the last three years on the Benchmark exam. School A has typically had a free and reduced lunch population of over 70%, which means the majority of students, regardless of subpopulation, will be targeted for interventions in Mathematics and Literacy.

In the past decade, the suburban city for which the student populations were studied has shifted from a university community with a population of approximately 58,000 in 2000 to a diversified and growing city with an estimated 75,102 residents as of 2012 (U.S. Census Bureau, 2011). The city is the third largest city in Arkansas and is a part of a fast-growing metropolitan statistical area with an estimated 464,623 residents as of 2009. The school district includes 14 schools, and serves over 9,000 students in grades K-12. Such rapid population changes are reflected in the school system, as the student population exemplifies a wide diversity of abilities, backgrounds, and experiences. As of 2010, the changing school system hosted over 50 different languages. Of the 705 students at School A, 144 were ELL students (ADE, 2013). All schools in the district had implemented MAP testing during the 2010 school year, which is a periodic assessment of growth for individual students in Reading and Mathematics given three times per

year to students in grades K-10. This assessment measures the child's growth against the expected growth for any child at that same grade level. For the 2012 school year, only 62.75% of ELL students met their growth target in Literacy and only 66.67% of ELL students met the proficiency target for Mathematics. Slightly more students (67.92%) met their growth target for Mathematics (NORMES, 2013).

School Level Improvement Efforts

The following summary from the School A's ACSIP (Arkansas Consolidated School Improvement Plan) document detailed the evaluation results. ACSIP Leadership Teams were formed and an analysis of the test scores from the 2010 administration of the K-7 grade Augmented Benchmark and SAT 10 Exams were completed. The team examined the results from both the combined population and each subpopulation and conducted data analysis to determine our main areas of weakness. In addition, they studied the three most recent years of attendance, disciplinary, formative and summative achievement data across grade levels within our building. They aggregated and disaggregated all the data for the purpose of establishing student learning and behavioral goals and looked at trend data in order to better identify the specific areas of need and help align classroom instruction with our curriculum, assessment and professional development. Routines, customs, and norms were examined in order to dig deeper for the root cause of students not achieving to their full potential. 2010 Supporting Data Statements showed the discrepancies in achievement, among various populations. Curriculum, instruction, assessment and professional development practices were modified to better meet the needs of all populations. Based on data analysis, the following areas reflect the greatest need within the Literacy Priority: Researched-based instructional strategies and literacy block

schedule. Literacy protocols were implemented from the district and building. In addition, grade level teams met weekly in K-4 and daily in 5-7 and as an entire faculty bi-weekly to review formative, real time classroom performance data for the purpose of making decisions regarding the direction, and focus, of our classroom instruction.

Three years of assessment results from the SAT 10 norm-referenced test were also examined (NORMES, 2011). At grade five, the reading comprehension national percentile rank has risen from 56 to 70, which is a 25% increase. Likewise, the math problem-solving percentile rank has risen from 55 to 69, indicating a 25% increase. The increases in achievement were evident in all sub-population areas, yet the achievement gap between the combined population and the LEP and SPED subpopulations remained consistent. In addition, the curriculum management audit performed in 2010 by the Phi Delta Kappa group showed achievement gaps among subgroups of students that are increasing over time; student groups are not experiencing equal success (fayar.net, 2011). School A has representation on the Curriculum Coordinating Council (CCC), which is responsible for leading learning and driving improvement and increased student achievement for the district. The efforts of the CCC were also a result of the Phi Delta Kappa curriculum management audit. In addition, administration at School A, together with district administration, has determined the greatest need for individualized attention is present in the ELL and SPED student populations.

Preliminary Study Methodology

This initial study was a quasi-experimental design because there was not random selection of participants. Instead, all students who were part of the SuccessMaker intervention and have MAP pre and post tests on file were included in the treatment group. This is known as a

quasi-experimental design, meaning that the researcher lacks full control over the scheduling of the experiment, but has full access to data collection procedures. Other students who did not receive the SuccessMaker intervention, but had pretest scores equal to the treatment group, were included in the control group. The control group gave valuable baseline data, and the treatment group experienced a specialized treatment, like the SuccessMaker program, to see if there was a significant difference in the performance of the two groups. In addition, this study is considered ex post facto (after the fact) because the students' pretests and posttests have already been completed. The interest was in the difference between the means of the posttest scores for the two groups.

Group 1, the SuccessMaker group correlation coefficient was r =.8923, (r squared = .7962) and Group 2 (control group) was r = .8468 (r squared = .7171). This means there was a strong linear relationship between the two values for each group, because values between .7 and 1.0 indicate a strong positive linear relationship. The value of r squared indicated the percent of variation in one variable explained by the other variable. Although the relationship is not a perfect linear one, the values are close enough to 1.0 to say there is a strong linear relationship.

Preliminary Study Instruments and Data Analysis

The *t*-test compared the means between the two variables for each group, and tests to see if the average difference is significantly different from zero. This test was chosen because the criterion variable, MAP scores, was an interval level of measurement. The predictor variable, class participation in SuccessMaker, was the nominal-level variable with only two categories. Each pair of pretest was matched to control for differences on the front end of the analysis. Random sampling was not possible for this study because of the matching of pretests.

Null Hypothesis: There is no significant difference between the means of post-RIT scores of the treatment group (SuccessMaker) and the non-treatment group. Alternate Hypothesis: There is a significant difference between the means of post-RIT scores of the treatment group (SuccessMaker) and the non-treatment group. The predictor variable is the participation (yes or no) in the SuccessMaker program, which is a nominal variable. The Criterion variable is the MAP post scores, which is an interval variable. If the probability (p) value for the F-test is less than .05, then the null hypothesis of no differences in variance is rejected and concluded the variances are unequal. But, since it was greater than .05, the null was not rejected. Variances were equal. A t-test was conducted to compare posttest MAP scores of SuccessMaker (treatment) and control groups. There was a significant difference in the scores for SuccessMaker (M=217.10, SD=14.49) and control (M=209.80, SD=13.32) conditions; $t(114)$=2.80, $p = 0.006$. These results suggested that the SuccessMaker intervention has an effect on student achievement, specifically MAP scores, which test growth over time. Precisely, the results suggest that when students participate in the SuccessMaker intervention program with fidelity, they show more growth over time. The effect size was calculated with Cohen's $d = .5245$. This is a measure of strength or magnitude in the relationship between variables.

Using the difference scores from the pretest to the posttest for the two groups, the difference scores were used in the next analysis. The difference scores were compared between the group of students who were involved in the SuccessMaker intervention and those who were not, using a t-test. If the p-value for the F-test is $< .05$, then we reject the null hypothesis of no differences in variances. Variances are considered unequal. A t-test was conducted to compare difference scores of SuccessMaker (treatment) and control groups. There was a significant

difference in the scores for SuccessMaker (*M*=14.78, *SD*=6.62) and control (*M*=7.53, *SD*=7.56) conditions; $t(112.02) = 5.49$, $p = 0.001$, with an effect size, calculated with Cohen's $d = 1.019$. This is a very large effect size. These results suggest that the SuccessMaker intervention has an effect on student achievement, specifically MAP difference scores from fall to spring. Precisely, the results suggest that when students participate in the SuccessMaker intervention program with fidelity, they show more growth over time.

Data Analysis of Linking Study

The NWEA linking study for Arkansas was the source of information linking a student's MAP score with his or her appropriate proficiency level on our Arkansas Comprehensive Testing, Assessment and Accountability (ACTAAP) Benchmark exams (NWEA, 2012). A linking study was performed to determine how closely the MAP assessments aligned with predictions on the Benchmark tests. These statistics showed the degree to which MAP and the Augmented Benchmark Exam were linearly related, with values at or near 1.0 suggesting a perfect linear relationship. The scores in the study showed a range from .77 to .87, which suggested a highly linear relationship. This information can be used to understand the predictive validity of MAP with respect to the ACTAAP, where, at least 86% of the time, the MAP score correctly linked to the eventual proficiency level of the student's spring ACTAAP score. Figure 4 shows ACTAAP LEP proficiency percentages from 2009-2012 for the district (Fayetteville Schools, 2014). The chart shows fluctuations, inconsistencies and, in some cases, negative trending achievement scores for LEP students. The reason MAP scores were used for this study were for consistent validity and reliability measures, and because the Rasch Interval Unit (RIT) scores reported show progress towards predicted growth over time, instead of proficiency for

state level benchmarks.

	3rd	4th	5th	6th	7th	8th	Algebra
2009	67.6	71.9	54.8	77.4	66.7	58.0	70.3
2010	63.5	66.7	63.2	72.9	74.5	37.9	64.1
2011	78.0	64.0	57.0	63.0	73.0	51.0	73.0
2012	76.6	77.0	62.5	61.5	78.0	39.5	70.0
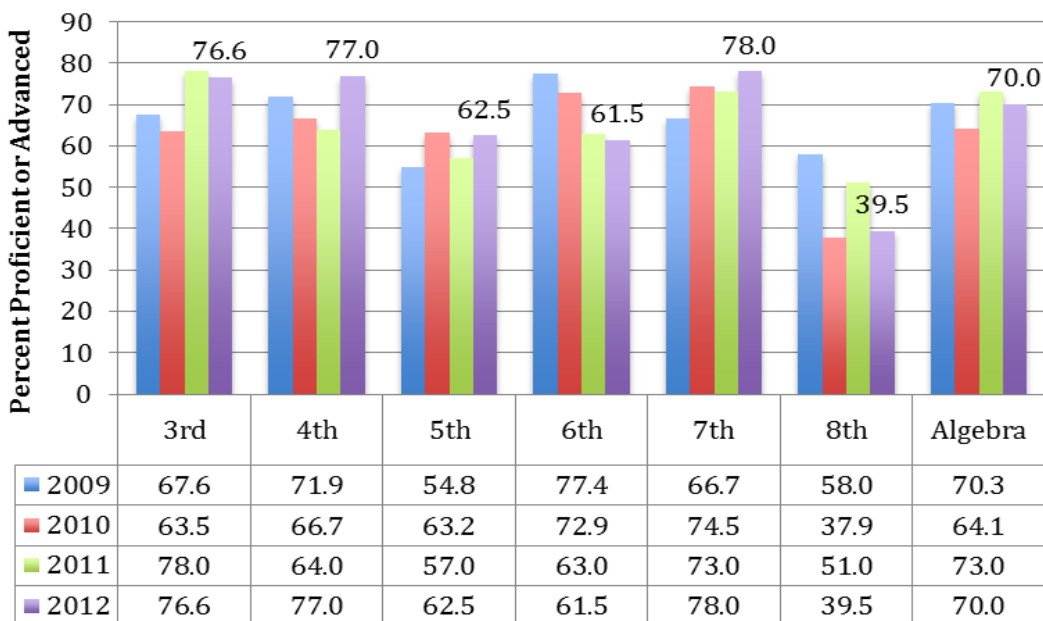
Figure 4. ACTAAP math assessment proficiency rates from 2009-2012 for Fayetteville Schools.

The chi-square test of independence or chi-square test of association or homogeneity is appropriate when both sets of variables are assessed on a nominal level of measurement, like the ACTAAP proficiency levels. They are classification variables, such as Below Basic, Basic, Proficient and Advanced. A contingency table was constructed using each of the 58 pairs and the frequencies for each of the 16 possible outcomes are completed. If the SuccessMaker program had been successful for the treatment group, more of the frequencies would occur in the lower half of the chart because this is where the proficient and advanced classifications are located for the treatment group. In looking at the chi-square table, there are more students who fell in the proficient and advanced category (84.48%) from the treatment group that had SuccessMaker than the control group (65.51%) that did not. The Chi-Square statistic was relatively small at 37.4279 with 9 degrees of freedom. The probability was less than .0001, meaning there is less than one chance in 10,000 of obtaining a chi-square value this large (or larger) if the variables

were independent in the population. Table 2 shows the Chi-Square analysis results.

Table 2

Results of Chi-Square Test and Descriptive Statistics by Treatment Status

Treatment Frequency Percent Row Percent Col Percent	Control				Total
	1-BB	2-B	3-P	4-A	
1-BB	2	1	0	0	3
	3.45	1.72	0	0	5.17
	66.67	33.33	0	0	
	40.00	6.67	0	0	
2-B	0	5	1	0	6
	0	8.62	1.72	0	10.34
	0	83.33	16.67	0	
	0	33.33	7.69	0	
3-P	1	6	3	2	12
	1.72	10.34	5.17	3.45	20.69
	8.33	50.00	25.00	16.67	
	20.00	40.00	23.08	8.00	
4-A	2	3	9	23	37
	3.45	5.17	15.52	39.66	63.79
	5.41	8.11	24.32	62.16	
	40.00	20.00	69.23	92.00	
Total	5	15	13	25	58
	8.62	25.86	22.41	43.10	100

Note. Abbreviations for proficiency classifications were BB for Below Basic, B for Basic, P for Proficient, and A for Advanced.

The conclusion for School A was to continue using the SuccessMaker program.
The program, when used with fidelity, appears to be performing to the specifications of the
Pearson Company. MAP RIT scores across the district will continually be monitored to
determine if SuccessMaker is the very best product for supplemental interventions for our
students. In order to provide a more comprehensive analysis of CAI programs across the district,

a more comprehensive statistical test was provided in this dissertation by way of repeated

measures ANOVA. Another year of MAP data was added for third and fourth grade students,

along with additional schools that do and do not use CAI programs to supplement the

curriculum.

Limitations of Past Research

The following are limitations of prior research prevalent in the review of literature. Time

on task and minutes of use varied greatly across the studies. In some of the studies, the span of

time between pretest and posttest was only a few months. Therefore, there may not have been

enough time to demonstrate significant differences in student achievement. There may also have

been a novelty effect of increased attention for a short period of time not realized in a long-term

research project. There were very few studies that reported results by LEP or ELL status. Studies

involving regular education or special education students cannot be generalized to the LEP and

ELL student populations. There were also very few studies specifically examining upper

elementary mathematics and CAI. Studies on primary, middle or high school grade ranges

cannot be generalized to upper elementary student ranges. In addition, there were few studies

examining these adaptive CAI mathematics programs as a supplement to core math instruction.

In summary, the review of the literature is mixed and lacking with regard to using CAI as

a supplement for ELL students as part of a sheltered instructional approach. At-risk language

learners need extra, meaningful practice working on prerequisite skills and grade-level skills.

They need differentiated instruction in an engaging, linguistically rich environment, with lots of

feedback from their peers and teachers alike. Although CAI programs contain these sought-after

sheltered components and provide targeted supplemental instruction and practice for a more

engaging learning experience, the research on SuccessMaker and Compass Odyssey programs show mixed results. The studies did not consider subpopulations of upper elementary ELL students. The studies were not performed over an extended amount of time with multiple data points for each year. Clements, Sarama, Spitler, Lange and Wolfe (2011) cited positive research for curriculum with a CAI component for elementary students, but the study was only for Pre-K and did not break down the results by ELL status. Various other studies on both the SuccessMaker and Compass Odyssey program have been completed, but none of them inform sufficiently with shortcomings illustrated in the bullet points above. This study was unique because it examined CAI supplemental interventions with third and fourth grade ELL students, a population and grade band not thoroughly researched. Furthermore, the implementation of CAI in this study was part of an overall pedagogical intervention of sheltered instruction designed to enhance the ELL students learning of mathematics.

CHAPER 3: METHODOLOGY

Chapter 3 Introduction

The purpose of this study was to examine the impact of CAI supplemental

implementation on student achievement as measured by MAPS assessment data, and to

determine if the CAI supplement was more beneficial than TI alone. In the main study for this

dissertation, there were six testing windows examined in the study: fall 2011, winter 2011, spring

2012, fall 2012, winter 2012 and spring 2013. The two CAI programs used at the elementary

level were SuccessMaker and Odyssey. The goal of the study was to determine the effectiveness

of these computer-assisted instruction interventions from a program evaluation perspective. The

relationship between student growth in mathematics and participation in intervention programs

was examined to be able to make informed decisions for the mathematics and ESL programs in

the future. All students in the district with MAP RIT scores for third and fourth grade were

included in the main study. Here are the research questions for main study:

Research Questions

Question 1: What was the effect of computer-assisted instruction on mathematics

achievement scores for third and fourth grade students?

Question 2: Was there a significant difference in the mathematics achievement of

third and fourth grade regular education (non-ELL) students who experienced

traditional instruction supplemented with computer-assisted instruction?

Question 3: Was there a significant difference in the mathematics achievement of

third and fourth grade ELL students who experienced traditional instruction

supplemented with computer-assisted instruction?

Hypotheses

Based on these guiding research questions, the following hypotheses were framed to evaluate the data.

H_1: There is a significant difference in the mathematics achievement of third and fourth grade students who experienced traditional instruction supplemented with computer-assisted instruction.

H_2: There is a significant difference in the mathematics achievement of third and fourth grade regular education (non-ELL) who experienced traditional instruction supplemented with computer-assisted instruction.

H_3: There is a significant difference in the mathematics achievement of third and fourth grade ELL students who experienced traditional instruction supplemented with computer-assisted instruction.

This chapter will include the type of research design, details on the population of participants, the methodology and procedures, measurement instruments, and the data collection and statistical analysis. Because the data has already been collected, this study is considered a post-hoc study, and does not have a true random experimental design. The researcher wishes to evaluate the benefit of CAI across the district to ascertain whether the programs in existence are effective in raising student achievement, especially with regard to the ELL subpopulation of students.

This study consisted of two groups, those who were exposed to the CAI supplement to the math curriculum (treatment group), and those who were not (control group). In addition, students were classified in the ELL subpopulation or not, according to their data in the Arkansas

Public School Computer Network (APSCN) system. The treatment group of students receives

both the traditional curriculum of Everyday Math and the supplemental CAI curriculum of either

Odyssey Math or SuccessMaker Math. The control group receives only the Everyday Math

curriculum.

Instead of a simple pretest posttest design, MAP data was collected at a baseline in the

fall (time 1), and also two post-treatment dates in winter and spring (time 2 and time 3) over the

course of two school years. The supplemental CAI curriculum is introduced after the first fall

assessment, and then is ongoing until the spring assessment of both years studied.

Participants

The population in this study was comprised of elementary school students in grades three

and four, from a suburban school district in northwest Arkansas. There were 614 participants

from eight elementary schools and one Pre-K-7 building. According to the 2010 US Census, the

majority of students in this district were Caucasian (83.8%), with 6% Black, 6.4% Hispanic or

Latino, 3.1% Asian and 1.1% Native American. There were over 9,000 students enrolled in the

district. At the time of the study, the district was comprised of eight elementary K-5 schools, two

middle schools, two junior high schools, one high school, and one Pre-K-7 building. Five of the

elementary schools used some form of CAI and four did not. The average time of participation

for all CAI students was 15.10 hours over the course of one school year. This participation in

CAI is the treatment group. All students included in the study were in third grade in the fall of

2011 and fourth grade in the fall of 2012. There were 309 females in the study and 305 males.

Fifty-three of the students were classified as ELL (30 Female and 23 Male) students in both the

2011-2012 school year and the 2012-2013 school year. The remaining 561 students (278 Female

and 283 Male) were classified as non-ELL.

Data Collection and Timeline

Measures of Academic Progress (MAP) assessment RIT scores were obtained from the

district for all students in the third and fourth grade across the 2011-2013 school years.

Participants were eliminated if they did not have all six data points for the two school years, did

not have consistent classification of ELL status, or did not have consistent enrollment in any

school building. The ex post facto data analysis was performed in February of 2014. Traditional

instruction is defined as the Everyday Math curriculum, offered at all elementary schools in the

district. CAI is defined as participation in SuccessMaker or Odyssey.

Measures

MAP tests are computer-adaptive assessments that adjust to the student's level. The test

starts at the student's grade level, and adjusts up or down, again and again, in response to correct

or incorrect answers from the student (NWEA, 2012). ACTAAP assessment results indicate if a

student has mastered grade-level standards according to Arkansas Frameworks, while MAP tests

determine where the student stands in comparison to other students nationwide in various

subjects. Using the DesCartes chart, which is also individualized for each student, specific skill

recommendations are made at appropriate levels for each child. These charts can also be shared

with parents to extend the learning to home.

All students in grades 3-9 were given the Measures of Academic Progress (MAP)

Assessment. Northwest Evaluation Association (NWEA) provided Measures of Academic

Progress (MAP) assessments for the district three times per year to measure academic growth for

individual students over time, regardless of their grade or school or program (Fayetteville

Schools, 2012). These assessments produced student RIT scores on a scale that uses individual

item difficulty values to estimate student achievement. The scale for these RIT scores is an

equal interval scale, which means the difference between scores is equally spaced. Students

were placed on the RIT scale regardless of grade level. There must be sufficient range to

accurately measure students with the highest achievement levels in each subject area. For

example, in reading, a RIT score of 245 is at the 93rd percentile in grade 10. So, even the tenth

graders can receive an accurate measure of their actual skill and ability (NWEA, 2012).

Validity and Reliability

The extensive item bank of questions used on the NWEA Measures of Academic

Progress (MAP) tests have been developed over a substantial period of time. This has given staff

charged with statistical analysis abundant opportunity to establish the reliability of the tests. The

result has been the collection of a significant amount of reliability evidence over time. Test and

re-test studies have consistently yielded statistically valid correlations between multiple test

events for the same student. Most such studies rely on the methodology of having students re-

test within several days (NWEA, 2012). NWEA test and re-test studies have typically looked at

scores from the same students after a lapse of several months. Despite this methodology (which

would have the expected result of lowering the correlation figures) the reliability indices have

consistently been above what is considered statistically significant. Internal reliability (reliability

between test items) has also been substantiated (Ary & Jacobs, 2002). This is all the more

remarkable in view of the volume and breadth of the item bank, and the fact that MAP is an

adaptive test. MAP users can be confident of the reliability of their tests. The rigor that has been

applied to the reliability studies has left no doubt that the MAP assessment system has been

constructed, and continues to be maintained, in a manner that assures more than adequate

reliability (NWEA, 2012).

Alignment studies are required to make a valid correlation between MAP and State

Mastery tests. A number of these correlation studies have been completed, including those for

Arkansas. These alignment studies have proven to be useful for teachers and building

administrators in helping to identify students for remediation prior to taking the state-mandated

test. A linking study was performed in 2010 to determine how closely the MAP tests are aligned

with the ACTAAP tests. These statistics show the degree to which MAP and the ACTAAP

exams are linearly related, with values at or near 1.0 suggesting a perfect linear relationship, and

values near 0.0 indicating no linear relationship. Since the scores range from .77 to .87, this

indicates a highly-correlated relationship. This information can be used to understand the

predictive validity of MAP with respect to the ACTAAP, where at least 86% of the time the

MAP score correctly linked to the eventual proficiency level of the student's spring ACTAAP

score.

Independent and Dependent Variables

Upon reviewing the data, the researcher identified the independent and dependent

variables for this quasi-experimental study. The independent variables were participation in CAI,

as well as ELL status. The dependent variable was mathematics achievement as measured by the

MAP assessment.

Statistical Analysis

The repeated-measures factorial Analysis of Variance (ANOVA) was used to test for

significant differences between the groups pretest and posttest time one and time two scores over

the course of two school years, for a total of six scores for each student. The .05 probability level was used as criteria to accept or reject the null hypothesis. Using SAS software, the PROC MEANS and PROC GLM repeated was run. In the main study, there were three research questions examining the pretest and five subsequent posttests of 614 participants over the course of the 2011-2012 and 2012-2013 school years.

CHAPTER 4: ANALYSIS OF DATA

The purpose of this study was to examine the impact of CAI supplemental implementation on student achievement as measured by MAPS assessment data, and to determine if the CAI supplement was more beneficial than TI alone.

Question1: What was the effect of CAI on mathematics achievement scores for third and fourth grade students?

Question 2: Was there a significant difference in the mathematics achievement of third and fourth grade regular education (non-ELL) students who experienced traditional instruction supplemented with computer-assisted instruction?

Question 3: Was there a significant difference in the mathematics achievement of third and fourth grade ELL students who experienced traditional instruction supplemented with computer-assisted instruction?

H_1: There is a significant difference in the mathematics achievement of third and fourth grade students who experienced traditional instruction supplemented with computer-assisted instruction.

H_2: There is a significant difference in the mathematics achievement of third and fourth grade, regular education (non-ELL) who experienced traditional instruction supplemented with computer-assisted instruction.

H_3: There is a significant difference in the mathematics achievement of third and fourth grade ELL students who experienced traditional instruction supplemented with computer-assisted instruction.

Examination of Questions and Hypotheses

Research Question 1 relates to Hypothesis 1, Research Question 2 relates to Hypothesis 2 and Research Question 3 relates to Hypothesis 3. Question 1 is the primary research question. To analyze these questions, repeated measures ANOVA to test for significance in the MAP assessments collected. Wilks' Lambda was the test used to analyze the significance of variations in MAP scores across the two school years. Tests of Sphericity was used to measure assumption violations when testing the within subject effects. The Greenhouse-Geisser Epsilon correction formula was applied where sphericity assumption was violated. The findings are presented in three sections, one for each research question and corresponding hypothesis.

Findings for Research Question 1

This section includes findings for Research Question 1: What was the effect of CAI on mathematics achievement scores for third and fourth grade students? A repeated measures analysis of variance (ANOVA) was used to test hypothesis 1. The interaction effect was statistically significant for CAI over time for all CAI participants in the study, including ELL and non-ELL students. $F(5, 3060) = .9254$, $p < .001$. However, the math MAP RIT scores for TI only students were higher, though not significantly higher. The results from the means procedure is shown in Table 4 for all students, and in Table 5 for CAI students. The means and standard deviations for the sample, as well as the minimum and maximum math MAP RIT scores, are shown in Table 4 and Table 5. The summer loss is evident in the mean column from spring of 2012 to fall of 2012. As time progressed, the spread of scores was greater, but the minimum scores at each testing window seemed to stagnate or regress. The maximum scores advanced 20 points from fall 2011 to spring of 2013 for all participants in the study. H_1 was rejected because

there was not a significant difference in the mathematics achievement of third and fourth grade students who experienced traditional instruction supplemented with CAI when compared to traditional instruction alone.

Table 4

Results from the MEANS procedure for all participants (N = 614)

Variable	Mean	Std Dev	Minimum	Maximum
F11_RIT	195.58	11.90	146	232
W11_RIT	201.99	11.90	154	232
S12_RIT	208.66	12.99	150	239
F12_RIT	205.53	12.65	149	239
W12_RIT	211.19	12.31	154	242
S13_RIT	217.78	13.54	150	252

TI math MAP RIT scores ranged from a minimum of 146 to a maximum of 252 across all testing occurrences. CAI math MAP RIT scores ranged from a minimum of 154 to a maximum of 250 across all testing occurrences. The maximum scores for CAI participants advanced 28 points from fall 2011 to spring 2013. There were 614 total students in the study, with 255 of them CAI students and 359 of them TI students.

Table 5

Results from the MEANS procedure for CAI participants (N = 225)

Variable	Mean	Std Dev	Minimum	Maximum
F11_RIT	196.38	11.89	154	222
W11_RIT	201.35	12.62	154	229
S12_RIT	208.90	13.44	150	239
F12_RIT	205.87	13.10	149	239
W12_RIT	211.27	12.90	154	237
S13_RIT	216.99	14.32	150	250

A repeated measures analysis of variance (ANOVA) was used to test hypothesis 1. Table 6 shows the interaction of CAI and TIME. The interaction effect was statistically significant for CAI over time for all CAI participants in the study, including ELL and non-ELL students. $F(5, 3060) = .9254$, $p < .001$. However, when compared to the TI group in Table 7, the means of the CAI were not significantly higher

Table 6

Repeated measures ANOVA for CAI* TIME interaction

Effect	df	SS	MS	F	Greenhouse-Geisser
CAI	5	172885.01	34577.01	1488.36	< .001
Within groups	5	812.08	162.42	.9254	
Total	3060	71088.83	23.23		

Table 7

Repeated measures ANOVA comparing CAI to TI

Effect	df	SS	MS	F	p
Between Subjects	1	.19	.19		
Group	612	508598.71	831.04	.00	.99
Total	613	508598.90	831.23		

Figure 5 shows the mean math MAP RIT scores graph over the 6 testing occurrences, comparing CAI to TI. Notice the summer loss from spring 2012 to fall 2012. Figure 5 shows mean math MAP RIT scores of CAI students are compared to math MAP RIT scores of TI students, the mean values for CAI are not significantly higher. $F(1, 612) = .00$, $p = .99$. Again, this means that hypothesis 1 is rejected.
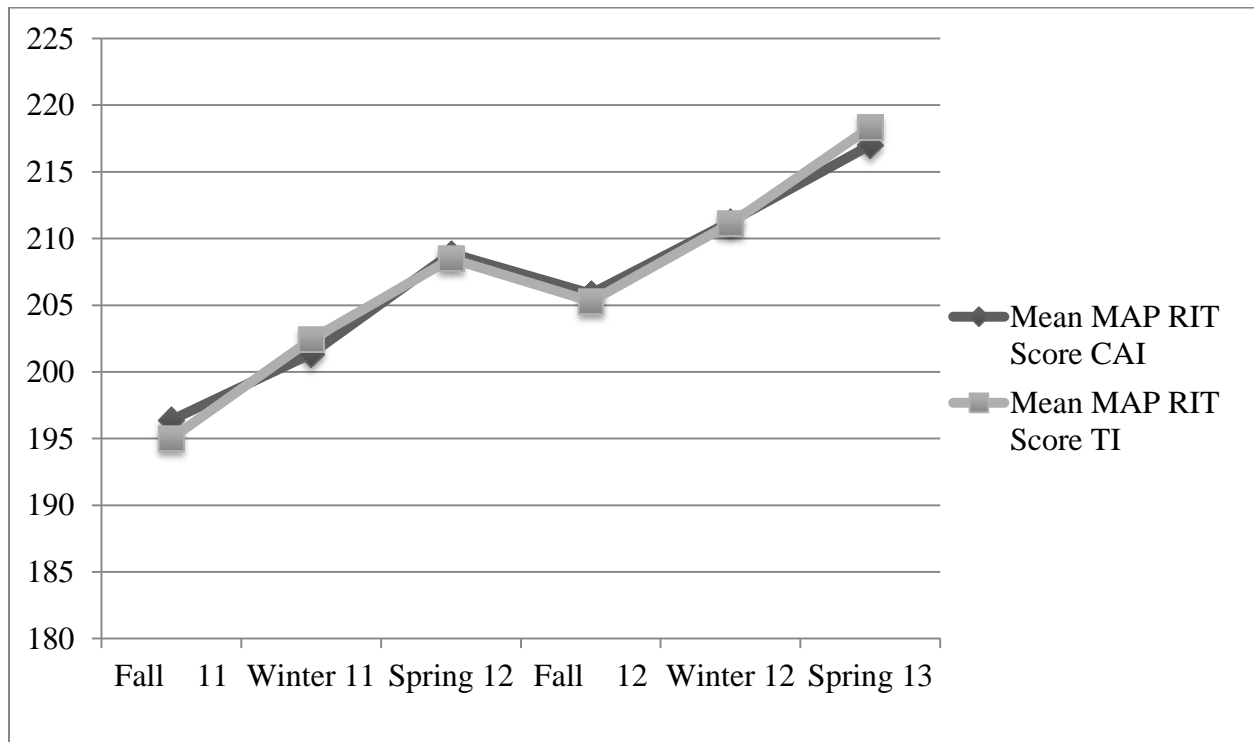

Figure 5. Mean math MAP RIT scores for CAI compared to TI.

Findings for Research Question 2

This section contains findings for Research Question 2: Was there a significant difference in the mathematics achievement of third and fourth grade, regular education (non-ELL) students who experienced traditional instruction supplemented with computer-assisted instruction? Table 8 shows the results from the means procedure for non-ELL students. Again, the spring to fall dip shows up with a 3.19 loss over the summer months. There were 561 non-ELL students in the study.

Table 8

Results from the MEANS procedure for non-ELL students (N = 561)

Variable	Mean	Std Dev	Minimum	Maximum
F11_RIT	196.18	11.78	146	232
W11_RIT	202.61	11.95	154	232
S12_RIT	209.30	12.96	150	239
F12_RIT	206.11	12.69	149	239
W12_RIT	211.78	12.26	154	242
S13_RIT	218.42	13.55	150	252

Table 8 shows the chart for mean math RIT scores for the non-ELL TI group and the non-ELL CAI group. For non-ELL students, CAI did not exact the growth in math MAP RIT scores that TI did. Table 9 ANOVA shows the scores for non-ELL CAI students were not significantly higher than TI. $F(1, 559) = .01$, $p = .94$.

Table 9

Repeated measures ANOVA for non-ELL CAI

Effect	df	SS	MS	F	Greenhouse-Geisser
CAI non-ELL	1	5.03	5.04	.01	.94
Within groups	559	462318.42	827.05		
Total	560	462323.45			

In Table 10, mean math RIT scores are compared for non-ELL TI and non-ELL

CAI students. The TI group showed a 12% growth, while the CAI group showed a 10%

growth across the two years of the study.

Table 10

Mean Math RIT scores for Non-ELL TI and Non-ELL CAI students

	Math RIT F 2011	Math RIT W 2011	Math RIT S 2012	Math RIT F 2012	Math RIT W 2012	Math RIT S 2013
Non-ELLTI Students	195.67	203.09	209.15	205.91	211.72	219.06
Non-ELL CAI Students	196.90	201.94	209.50	206.37	211.87	217.54

Note. The GLM Procedure run in The SAS System on Thursday, February 27, 2014.
There were 326 Non-ELL TI students and 235 Non-ELL CAI students.

In Figure 6, the graph shows the TI scores higher than CAI scores by the last

testing window. In addition, the differences from the beginning testing window to the end

were greater for the TI students (23.39) than for the CAI students (20.64).
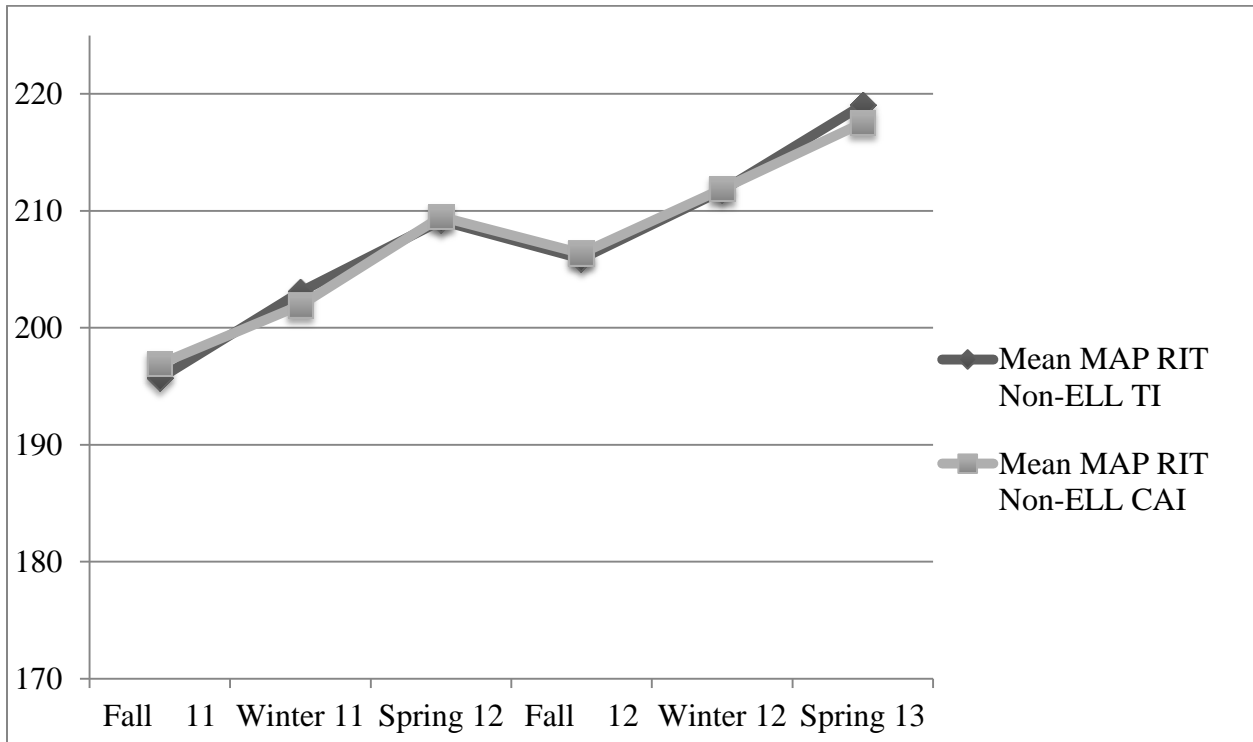
Figure 6. Mean math MAP RIT scores for non-ELL TI and non-ELL CAI.

The hypothesis H_2 was rejected because there was not a significant difference in the mathematics achievement of third and fourth grade non-ELL students who experienced traditional instruction supplemented with computer-assisted instruction when compared to traditional instruction alone.

Findings for Research Question 3

This section contains the findings for Research Question 3: Was there a significant difference in the mathematics achievement of third and fourth grade, ELL students? Table 11 shows the results from the means procedure.

Table 11

Results from the MEANS procedure for non-ELL students (N = 53)

Variable	Mean	Std Dev	Minimum	Maximum
F11_RIT	189.17	11.42	159	218
W11_RIT	195.47	9.12	176	218
S12_RIT	201.92	11.51	171	222
F12_RIT	199.36	10.50	177	228
W12_RIT	204.89	11.01	180	222
S13_RIT	210.96	11.48	187	234

Note. F11 and F12 refers to fall math RIT scores for that year. S12 and S13 refers to spring math RIT scores for that year. W11 and W12 refers to winter math RIT scores for that year.

The maximum ELL math MAP RIT scores rose 16 points across the six testing occurrences, and the means increased 12 percent during the same time frame. Table 12 shows the results from the repeated measures ANOVA for the ELL group. Mean math MAP RIT scores for ELL students were significantly lower than the non-ELL group. $F(1, 612) = 18.17$, $p < .001$.

Table 12

Repeated measures ANOVA for ELL

Effect	df	SS	MS	F	p
ELL	1	14665.56	14665.56	18.17	<.0001
Within groups	612	493933.34	807.08		
Total	613	508598.9			

In Table 13, mean math RIT scores are compared for ELL TI and ELL CAI

students. The TI group showed a 12% growth, while the CAI group showed an 11%

increase across the two years of the study.

Table 13

Mean Math RIT scores for ELL TI and ELL CAI students

	Math RIT F 2011	Math RIT W 2011	Math RIT S 2012	Math RIT F 2012	Math RIT W 2012	Math RIT S 2013
ELLTI Students	188.48	196.09	201.97	198.97	205.27	211.24
ELL CAI Students	190.30	194.45	201.85	200	204.25	210.50

Note. The GLM Procedure run in The SAS System on Thursday, February 27, 2014.
There were 33 ELL CAI students and 20 Non-ELL CAI students.

Figure 7 shows the comparison graph between the ELL CAI group and the ELL

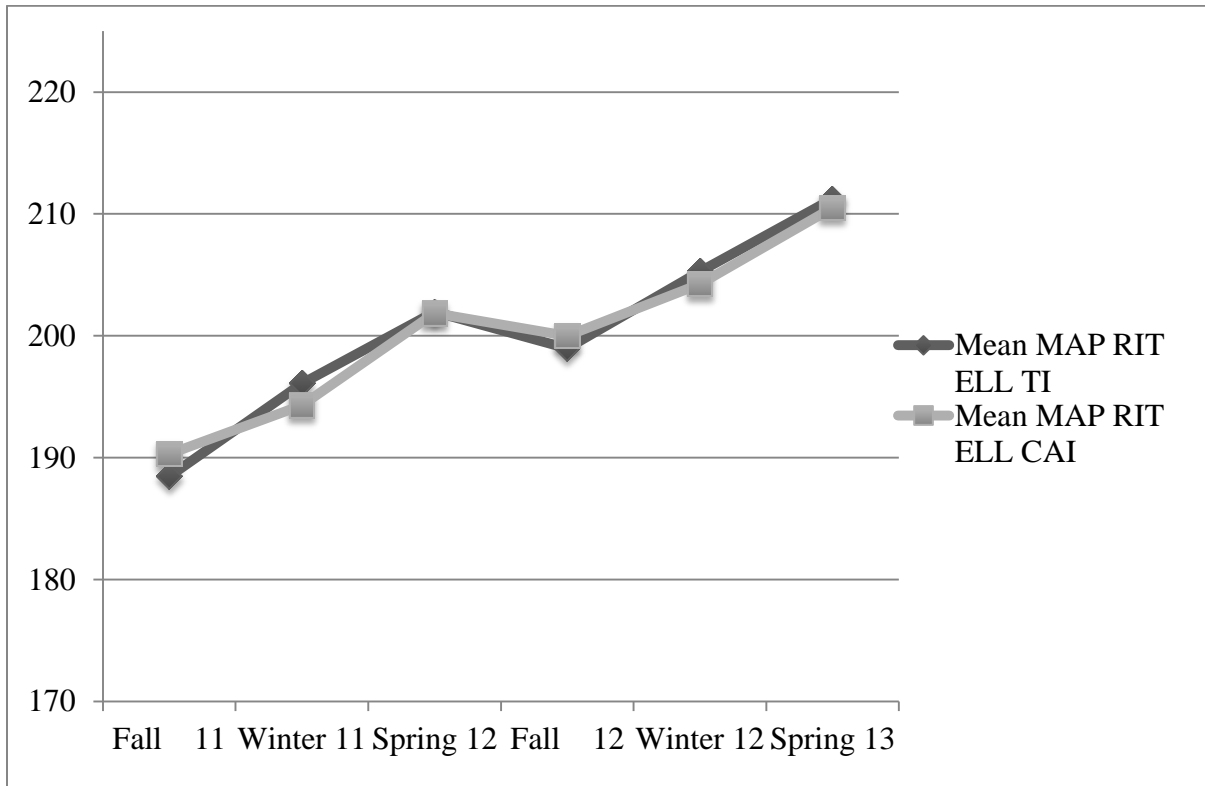TI group. Notice the summer loss from spring 2012 to fall 2013.

Figure 7. Comparison between ELL TI students and ELL CAI students.

Results were analyzed using an Analysis of Variance (ANOVA) with repeated measures for two different factors. The TIME*ELL*CAI interaction was not significant, $F(5,3050) = .16$, $p = .98$. The main effect of group (ELL) was significant $F(1,612) = 18.17$, $p < .001$, as was the effect of time $F(5, 3060) = 478.31$, $p < .001$. Post hoc contrasts found that math scores at the follow up sessions were significantly higher than scores observed at baseline. Figure 8 shows the scatter plot for all four groups, with the highest mean MAP RIT score achieved by the Non-ELL TI group, and the lowest achieved by the ELL CAI group.
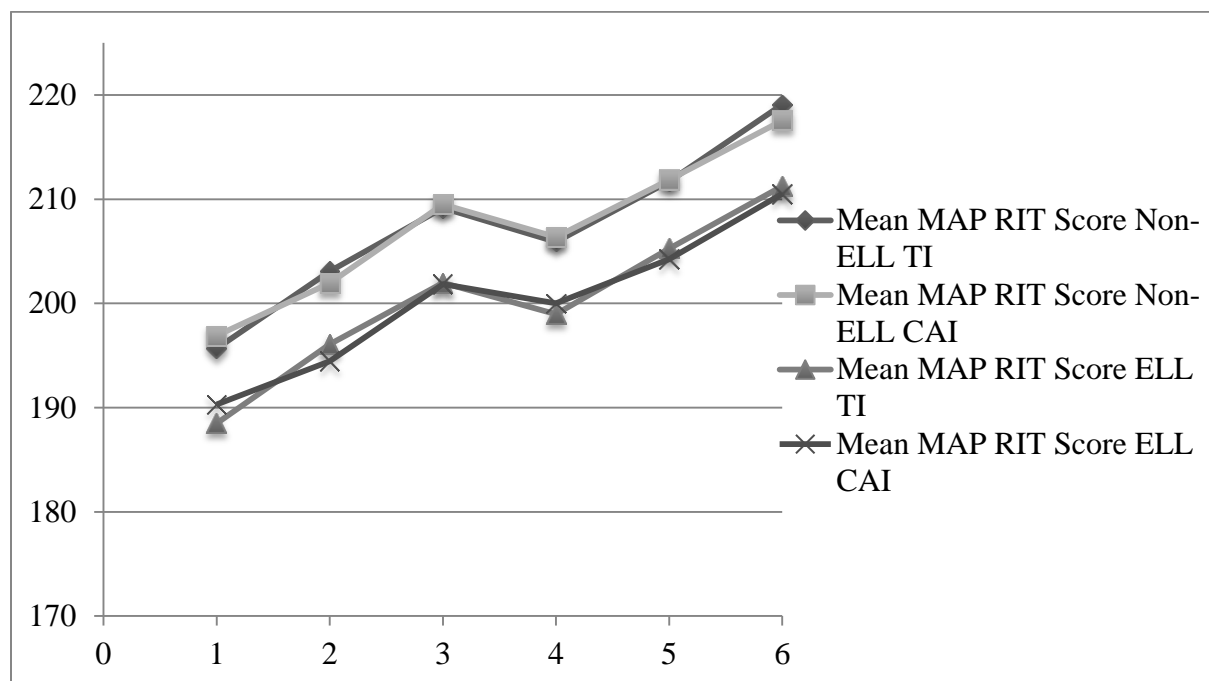
Figure 8. Mean math RIT scores for Non-ELL TI, Non-ELL CAI, ELL TI and ELL CAI students across the six MAP testing sessions from fall 2011 to Spring 2013.

Summary of Findings

Repeated measures ANOVA revealed significant differences in student math achievement over time for all groups $F(5,3060) = 478.31$, $p < .0001$. However, there was no significance found for the Time * ELL interaction $F(5, 3060) = .16$, $p = .98$. There were significant results for ELL, $F(1, 612) = 18.17$, $p < .001$. The Non-ELL students performed significantly better than their ELL counterparts. According to the Wilkes' Lambda Multivariate Test, there were no significant differences in the CAI group when compared to the TI group from fall 2011 to spring 2013 $F(1, 612) = .00$, $p = .99$. Chapter 5 provides a detailed summary and discussion of the quantitative findings.

CHAPTER 5: DISCUSSION

Summary of the Study

This chapter contains a summary of the study and answers three major research questions. The discussion of the findings is followed by limitations, conclusions, and implications for research and practice. The purpose of this study was to examine the impact of CAI supplemental implementation on student achievement as measured by MAPS assessment data, and to determine if the CAI supplement was more beneficial than TI alone. This study was a quasi-experimental, ex post facto, quantitative research design. The research questions examined CAI as a supplemental intervention for students through the lens of sheltered instruction in order to determine effect and effectiveness of the CAI interventions with ELL and non-ELL student groups. The statistical test used throughout was the repeated measures ANOVA. Data were gleaned from the district Director of Assessment, Data and Accountability with permission from the Superintendent of Schools. Status of students was reported from the district ESL database known as TELL. Statistics were run using the SAS software program. The significance level was set at .05.

Math MAP RIT scores for individual students were used. There were 614 students with MAP scores for all six testing windows. The testing windows spanned two school years from fall of 2011 to spring of 2013, which encompassed the students' third and fourth grade years. All third and fourth grade students with six MAP RIT scores were included from across the district's nine elementary schools, which included 30 different classrooms across the district. This data were used to answer the three primary research questions and determine whether the hypotheses were valid or invalid.

Conclusions and Implications

Question 1: What was the effect of CAI on mathematics achievement scores for third and fourth grade students?

The CAI group showed significant gains over time, as measured by the math MAP RIT scores. However, when using the repeated measures ANOVA analysis; compared to the TI group, the mean scores were not significantly higher. The ELL CAI students score higher in some testing occurrences than the ELL TI students, but the differences were not significant. When comparing all students in the study, CAI students averaged a 20.61 math MAP RIT score increase and TI students averaged a 23.33 math MAP RIT score increase.

Results are inconclusive with regard to use of CAI as a supplemental mathematics intervention for ELL students. Although the preliminary study with the SuccessMaker program at School A showed signs of significance, when the study was expanded to include more schools, another intervention program, and another three data points, results were not significant. A repeated measures analysis of variance (ANOVA) was used to test hypothesis 1. The interaction effect was statistically significant for CAI over time for all CAI participants in the study, including ELL and non-ELL students. $F(5, 3060) = .9254$, $p < .001$. However, the math MAP RIT scores for TI only students were higher, though not significantly higher. The goal of this study was to examine student achievement for students using MAP assessment scores and to examine CAI as a supplemental math intervention. H_1 was not supported in the study because there was not a significant difference in the mathematics achievement of third and fourth grade students who experienced traditional instruction supplemented with CAI when compared to

traditional instruction alone.

Question 2: Was there a significant difference in the mathematics achievement of third and fourth grade, non-ELL students who experienced traditional instruction supplemented with computer-assisted instruction?

The hypothesis H_2 was not supported because there was not a significant difference in the mathematics achievement of third and fourth grade non-ELL students who experienced traditional instruction supplemented with computer-assisted instruction when compared to traditional instruction alone. For non-ELL students, CAI did not exact the growth in math MAP RIT scores that TI did, and scores for non-ELL CAI students were not significantly higher than TI. Possible reasons for this development include, the non-ELL students being more comfortable with the TI model of instruction, rather than CAI. The TI group also had a higher socioeconomic rate than the CAI group. The repeated measures ANOVA comparing the non-ELL CAI group to the non-ELL TI group did not show significant results. $F(1, 559) = .01$, $p = .94$. When comparing non-ELL students in the study, CAI students averaged a 20.64 math MAP RIT score increase and TI students averaged a 23.390 math MAP RIT score increase.

Question 3: Was there a significant difference in the mathematics achievement of third and fourth grade ELL students who experienced traditional instruction supplemented with computer-assisted instruction?

Repeated measures ANOVA revealed significant differences in student math achievement over time for all groups, however results were not significant for the ELL students who experience traditional instruction supplemented with CAI. The hypothesis

H_3 was not supported because there was not a significant difference in the mathematics achievement of third and fourth grade non-ELL students who experienced traditional instruction supplemented with computer-assisted instruction when compared to traditional instruction alone. The maximum ELL math MAP RIT scores rose 16 points across the six testing occurrences, and the means increased 12 percent during the same time frame. The repeated measures ANOVA showed mean math MAP RIT scores for ELL students were significantly lower than the non-ELL group. $F(1, 612) = 18.17$, $p < .001$. When comparing ELL students in the study, CAI students averaged a 20.20 math MAP RIT score increase and TI students averaged a 22.76 math MAP RIT score increase.

A possible account for this development of non-significant results was that the traditional education only campuses lacked Title I funding that supported CAI for many ELL students. The schools without Title I funding implemented other interventions not analyzed as part of this study. These schools provided additional activities than TI alone, like small group tutoring activities outside the school day. It is possible that these interventions were more effective. Additional research would need to be conducted to confirm or refute this. In addition, some school level of implementation for CAI was weaker than others. The amount of time recommended by the publishers of the programs was minimal. Some CAI schools implemented with the minimal amount of time, and some implemented with more, which could be a causal fidelity of implementation issue. The district was also using more than one CAI program in this study SuccessMaker and Compass Odyssey. When only looking at the preliminary results for School A, there were significant findings with SuccessMaker.

Another explanation of non-significant results was that the poverty rates of the TI schools were lower than that of the CAI schools. The factor of poverty and outcomes on student learning are well-documented to impact negatively. The poverty rates at the different buildings in the district were also wide-ranging from 11.13% to 81.26%, while the district average is 41%.

Perhaps the most compelling reason there were no significant differences found between CAI and TI schools in this study was because the study did not capture all of the nuances of sheltered instruction. Although these programs contain many of the components of sheltered instruction, they only contain about 16% of the 30 components found in SI (Echevarria, Vogt, & Short, 2013). Teachers who work with ESL students do not always implement all 30 components of SI in the classroom setting. There are specific areas where ESL students need help, such as building background knowledge and making the incomprehensible comprehensible. ESL students need more wait time from the teacher because they are often translating their thoughts between languages, which requires reordering before speaking. Perhaps if the ESL students were getting all 30 components, there would have been significant growth in their scores.

Weaknesses identified in this study were related to the limited size of the student populations, the limited number of testing occurrences and the limited focus of the study. The preliminary study included only one school year, and only one building, with a matched t-test design. Expanding this to multiple schools, multiple programs and approaching the study from the sheltered instruction standpoint seemed to broaden the study sufficiently. It did not. The results from this study seemed to generate more questions than answers. Another weakness of the study was lack of qualitative information in the form of student and teacher interviews. If there had been a simple survey for each group, more pointed information could have been

gleaned as to why the CAI programs were effective or ineffective. Questions about the implementation process could have been asked to shed further light on the situation. The presence of certified teachers instead of instructional aides during CAI instruction time could also have been determined. The mixed-methods approach could have given more insight into why the CAI interventions were successful or unsuccessful.

The current sample size of 614 students is still very small, but larger than the preliminary study. The main study for this dissertation represented 9 elementary schools and 30 classrooms across one suburban school district. Repeated measures ANOVA tests were used to measure math MAP RIT scores across the 2011-2012 and 2012-2013 school years. This ANOVA test yielded more information than the previous matched-pair t-test. However, another three testing windows from an additional school year may add to the current research and be more informative.

The SI approach and constructivist learning theories point to CAI resulting in increased student achievement (Echevarria, Vogt, & Short, 2013). Even though the CAI student MAP RIT scores were not significantly higher than the TI scores, there were significant increases over time for students in both groups. There were also significant increases in ELL student scores and non-ELL student scores. There were even instances in isolated testing windows where the CAI MAP RIT scores topped the TI score averages. The scatter plots comparing the ELL and non-ELL groups showed parallel trends instead of the diverging trends hypothesized. The ELL student scores for this study ended up about one testing window behind the non-ELL student scores. The different instructional models in place did help students make gains in math student achievement; however we did not help our ELL students make catch-up growth. Perhaps the

constructivist-based professional development implemented the last two years will make a difference in math student achievement for all students in the coming years.

The prior studies showed mixed results in terms of student achievement. The results of this study are consistent with prior research. One possible explanation is the limited number of variables considered. The next section identifies additional variables that need to be included in the data gathering in order to provide a more complete picture of CAI within the SI model of instruction.

Recommendations for Practice

In the future, the practice of continual scrutinization of supplemental math interventions should be continued, especially with regard to fidelity of implementation with the district ELL students. In reflection, School A's initial observations showed some success in student achievement, which could have been due to superior implementation plans and superior execution. With the continued scrutiny, schools and teacher practices should be monitored more closely. More qualitative data is needed to ensure fidelity of implementation and use. This qualitative teacher and student data obtained by informal interviews would have added to the study in this dissertation, making it a more well-rounded mixed methods design.

Longitudinal data should continue to be gathered in order to better inform the decision-making process. This is especially important for specialized populations like the ELL student population. Since there has been MAP RIT data collected for only the last 5 years, continuing this process will be vital information for future curriculum plans and purchases. More qualitative data should be gathered by building to determine fidelity of

implementation and to determine if programs are consistently effective in exacting

student growth. If students are not showing growth as measured by MAP RIT scores,

implementation factors should be reconsidered.

This study has implications for school administrators and district decision-makers. The

district administrators should thoroughly research purchases of all new CAI programs and any

intervention program to determine if they have been scientifically proven effective. Efforts

should be made to seek studies with similar grade bands, student demographics, and planned

usage as this district. Perhaps heeding these recommendations for practice will lead to a more

substantial implementation, which in turn, could improve results for students across the district.

Recommendations for Further Research

In reflecting on the main study for this dissertation, there are recommendations for future

research. Future studies could be conducted with larger sample sizes. Second, this study could be

expanded to include CAI interventions across the K-12 spectrum to better gauge its

effectiveness. More information is needed for how the CAI supplemental mathematics program

affects learning and achievement in differing grade levels. In addition, if results could be

reported by location instead of holistically, variables concerning fidelity of implementation could

be measured and included in the data gathered. This could give researchers a better picture of

fidelity of implementation at the building level.

Research could also be concentrated on only one CAI program at a time. Adding multiple

programs into this study seemed to further confound the results instead of clarifying them. Test

data should be gathered longitudinally for multiple years. The time between the pretest and last

posttest should be longer than one year and seven months, which is the intervening time in this

study. More longitudinal data may give a more informed picture of failure or success of the program. This could be paired with more in-depth data about the students, such as their ethnicity and ELL levels.

The CAI intervention could be more effective with Hispanic students, or more effective with lower level ELL students than mainstream ELLs. Conducting a mixed-methods study, including a qualitative approach is also recommended. Questions concerning increased effort or encouragement of support from the certified classroom teacher could be asked. Attitudes of the students and teachers involved in CAI implementation could have an influence over the success or failure of the implementation. In a post-hoc studies like this one, there is no control over variables like free lunch rates. Since it is proven that students from high socio-economic backgrounds perform better in school, variables such as this should be controlled for in future studies. Finally, more information about the sheltered instruction components should be gathered, not just mediating tools like CAI. The teacher evaluation rubric will soon have components of sheltered instruction embedded into it. This data could be easily gathered to determine effectiveness of the sheltered instruction model as a whole, and its effectiveness with the ELL students in our district.

Summary

Examining the use of CAI math programs with ELL students was important because use of these programs is becoming more pervasive, and because the current research was lacking with their use in upper elementary grades. The National Mathematics Advisory Panel (2008) recommended more research on topics of math education, such as randomized controlled designs

or rigorous quasi-experimental designs. These research studies could inform practice that may lead to improved math achievement.

This study sought to determine the impact CAI programs had on the math MAP RIT scores of third and fourth grade students in the district. Both ELL and non-ELL students were included in the study to determine if the CAI programs were more successful with either group. Results indicated that use of CAI does not exact significantly different math achievement scores than TI alone, according to math MAP RIT scores. Results were analyzed using an Analysis of Variance (ANOVA) with repeated measures for two different factors. The TIME*ELL*CAI interaction was not significant, however, the main effect of group (ELL) was significant, as was the effect of time. Post hoc contrasts found that math scores at the follow up sessions were significantly higher than scores observed at baseline.

The overall conclusion from this study suggests that CAI alone is insufficient in exacting significant growth in student achievement scores as measured by the math MAP assessment. The CAI model while proven successful in many settings has only a small portion of the overarching 30 components of sheltered instruction necessary for optimizing learning for our ELL students. In addition, individual student success was dependent upon the cognitive effort they contributed. This falls in line with constructivists who argued that the learner must construct their own understanding, combining the new with the old, and the teacher, "does not give up his or her role as a guide but this leadership takes the form of encouraging and orienting the students' constructive effort rather than curtailing their autonomy by presenting ready-made results." (Von Glasersfeld, 2003, p.1). Additional active effort is required by the student, rather than passive participation. There is no substitute for the hard work and effort teachers and students must exert

to achieve sustained, successful student achievement. The art of teaching is creating the desire to learn in the student, rather than filling their minds with the correctly apportioned knowledge. It is more complicated than choosing the right supplemental CAI program for the student to use. Learning should be individualized at the student level. It is a common practice to provide this individualized support by providing additional opportunity for instruction and guided practice with feedback. CAI is one of many ways teachers can provide that additional opportunity, but it is not successful with all students, as shown by the results of this study. The goal is understanding, but there are many paths to attain it.

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APPENDIX: IRB APPROVAL

UNIVERSITY OF
ARKANSAS

Office of Research Compliance
Institutional Review Board

March 12, 2014

MEMORANDUM

TO: Christie Jay
                                       Laura Kent

FROM: Ro Windwalker
                                       IRB Coordinator

RE: PROJECT CONTINUATION

IRB Protocol #:   13-03-590

Protocol Title: *Impact of Mathematics Computer-Assisted Instruction on English
                                       Language Learners' Growth and Achievement*

Review Type: ☒ EXEMPT ☐ EXPEDITED ☐ FULL IRB

Previous Approval Period: Start Date: 03/25/2013 Expiration Date: 03/24/2014

New Expiration Date: 03/24/2015

Your request to extend the referenced protocol has been approved by the IRB. If at the end of this period you wish to continue the project, you must submit a request using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. Failure to obtain approval for a continuation on or prior to this new expiration date will result in termination of the protocol and you will be required to submit a new protocol to the IRB before continuing the project. Data collected past the protocol expiration date may need to be eliminated from the dataset should you wish to publish. Only data collected under a currently approved protocol can be certified by the IRB for any purpose.

This protocol has been approved for 650 total participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 210 Administration Building, 5-2208, or irb@uark.edu.

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