12-2008

The Effect of Inquiry-Based, Hands-On Math Instruction Utilized in Combination with Web-Based, Computer-Assisted Math Instruction on 4th-Grade Students' Outcomes

Jason D. Plourde

The Effect of Inquiry-Based, Hands-On Math Instruction Utilized in Combination with Web-Based, Computer-Assisted Math Instruction on 4th-Grade Students' Outcomes

By

Jason D. Plourde

A DISSERTATION

Presented to the Faculty of
The Graduate College of the University of Nebraska
In Partial Fulfillment of Requirements
For the Degree of Doctor of Education

Major: Educational Administration

Omaha, Nebraska

December 2008

<u>Supervisory Committee</u>

Dr. John W. Hill, Chair

Dr. Kay A. Keiser

Dr. Neal F. Grandgenett

Dr. Jody C. Isernhagen

UMI Number: 3324659

ABSTRACT

THE EFFECT OF INQUIRY-BASED, HANDS-ON MATH INSTRUCTION UTILIZED IN COMBINATION WITH WEB-BASED, COMPUTER-ASSISTED MATH INSTRUCTION ON 4TH-GRADE STUDENTS' OUTCOMES

Jason D. Plourde

University of Nebraska

Advisor: Dr. John W. Hill

Results indicated that 4th-grade students (*n* = 19) participating in the inquiry-based, hands-on math instruction used in combination with web-based, computer-assisted math instruction group and 4th-grade students (*n* = 19) participating in the inquiry-based, hands-on math instruction alone group did not significantly improve their pretest-posttest Problem Solving/Data Analysis, Concepts/Estimation, Math Total, and Math Computation norm-referenced normal curve equivalent achievement test score results. However, 4th-grade students participating in the inquiry-based, hands-on math instruction alone group posttest-posttest scores were statistically significantly greater than students who participated in the combination instruction group across all four subtests. Moreover, all posttest norm-referenced, Normal Curve Equivalent subtest scores for both groups were measured within the average range. On the criterion-referenced math test score posttest-posttest comparison, 53% of the 4th-grade students participating in the inquiry-based, hands-on math instruction used in combination with web-based, computer-assisted math instruction group compared to 37% of the 4th-grade students participating in the inquiry-based, hands-on math instruction alone group improved their posttest score results. Finally, no statistically significant differences between the two instructional groups were found for student absences, tardies, discipline referrals, and perceptions of math ability scores. Implications for improving math instruction are discussed.

ACKNOWLEDGEMENTS

First, I would like to thank Dr. John Hill for chairing my doctoral committee and for all of his expertise, guidance, encouragement, and leadership during this entire process. I am especially thankful to Dr. Hill for his aide with interpreting the statistical reprises and the nuances of this study. Thank you, Dr. Hill. I also would like to cordially acknowledge the rest of my doctoral committee, Dr. Kay Keiser, Dr. Neal F. Grandgenett, and Dr. Jody C. Isernhagen--all were instrumental in helping me achieve this important scholarly life goal at the University of Nebraska at Omaha. Thank you. I am also indebted to several central office colleagues for their support and encouragement. I would like to especially acknowledge Dr. Marty Shudak for his extensive and always timely assistance with numerous requests I placed to him related to my study. Thank you, Marty. I am also in debt to Dave Fringer for providing me access to all of the necessary district data to complete the study, usually on short notice. Thank you, Dave. I would also like to take this opportunity to publicly acknowledge God, faith, family, and friends, without which none of this would have been possible. I have consistently discovered that all of my accomplishments have always begun and ended with the aforementioned. Specifically, I am compelled to lovingly acknowledge my wife, Charadee, for her constant support and encouragement during this ever challenging, yet rewarding, endeavor. Thank you, Charadee, and I love you. I am also thankful to my three children, Stephen, Joseph, and Emily, for their patience and understanding on the occasions that Daddy had "homework" and was not available for them for a variety of wants and needs. Thank you, each, and I love you.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

TABLE OF CONTENTS (Cont.)

LIST OF TABLES

LIST OF TABLES (Cont.)

LIST OF TABLES (Cont.)

LIST OF TABLES (Cont.)

LIST OF TABLES (Cont.)

CHAPTER ONE

Introduction

Literature Related to the Study Problem

Today, throughout the world, advances in technology and the global economy are creating opportunities for growth and change. The effect of this change is being felt throughout all aspects of our lives and school-aged children are now at the forefront of these changes, according to the National Council of Teachers of Mathematics (NCTM, 2000). Educators, parents, and school reformers all assert that student mastery of mathematics is critical--the key--for keeping pace in a highly competitive global economy.

Furthermore, it is held that early success in mathematics studies will ultimately ensure equalized life opportunities and social justice for students by preparing them for futures filled with technological change and unknown challenges (Baker, Street, & Tomlin, 2006; NCTM, 2005; PLATO, Technical Paper #2, 2003; Research Advisory Committee, 2001).

While the elegance of the great early mathematical discoveries have not changed--since the Egyptians, Babylonians, and Chinese used it to design their magnificent architectural pursuits--the importance of mastering mathematical knowledge and its concomitant use in our everyday world has grown exponentially (Imhausen, 2006; Kulm, 2006; Remmert, 2004). Davitt (2000) maintains, "...our modern versions of mathematical theories are polished diamonds that started off as rough pieces of carbon" (p. 692).

The field of mathematics is constantly evolving and the importance of student mastery of math computation and math concepts, at all levels, while intense, never seems to keep pace (Kool, 2003; NCTM, 2003). This is why some advocate that elementary mathematics instruction is a obligatory place to begin the discussion about math reform (Landel & Nelson, 2007). Fortunately, there is a renewed interest in transforming the American educational system (Moores, 2004). However, most believe discussion and debate about how to improve the teaching of math is considered a non-negotiable endeavor (Ferrini-Mundy, 2001; Lappen, 2001).

While the debate about math instruction may, to some, seem too political (Silberman, 2003), effectively addressing improved math instruction holds great promise for the social and economic future of America's students who will have to compete in a technology-based global economy (Plato & Quinn, 2003). Poor math skills will keep many individuals from finding and keeping fulfilling careers in all walks of life (Broderick, Mehta-Parekh, & Reid, 2005; DeSimone & Parmar, 2006; Fennema & Sherman, 1976). As noted by the most recent NCTM (2000) standards, in the world of tomorrow, those who understand math will become leaders, and those who lack math knowledge will become followers. This is one reason why quality math curriculum and instruction is critical to our country's future (Ahlgen & Rutherford, 1993).

In fact, due to recent concerns surrounding the poor math scores of American students, as reported by the Third International Mathematics and Science Study (TIMMS, 2003), there is an overwhelming interest in discovering new and effective ways to teach math to all students (Edmonds & Li, 2005; Elmendorf, 2006; Gagnon & Maccini, 2007; Butler, Hudson, & Miller, 2006; Kulm, 2006; Mann, 2006). While the call is to help all students succeed in their math course work, many acknowledge that students who have been identified as most likely to fail in math or somehow believe that they cannot be successful in math classes present a great challenge to our schools today (Broderick, Mehta-Parekh, & Reid, 2005; Doe, 2005; Edmonds & Li, 2005; Butler, Hudson, & Miller, 2006). This is why teachers must be trained to teach math to students with all types of needs, as well as to differentiate their instruction for other individuals with greater math aptitude (Gagnon & Maccini, 2007; Meckstroth, Smutny & Walker, 1997). All students are entitled to the best education we can provide, regardless of needs, gender, disability, or socioeconomic status (Landel & Nelson, 2007).

Although the question has been around for some time (Moores, 2004), all the recent media attention and debate about how best to teach math to all children has brought the issue to the forefront of our public discourse (Dugdale, Guerrero, & Walker, 2004; Berk & Martin, 2001). Fortunately, this type of nationwide conversation actually promotes improvements within the field of mathematics, improving student success, and making our programs more competitive, especially on the world market (Ferrini-Mundy, 2001). In the hopes of making a positive difference, the US government continues to transfer federal funds into local educational agencies--now calculated to be over $350 billion for public education alone (Renzulli, 2005).

As it stands now, however, America is not doing very well on the competitive, world market. According to the National Center for Educational Statistics, the United States is not in the top ten, when ranked against other developed countries for math achievement (TIMMS, 2003).

This is one reason why improved math curricula and teaching methods that will improve the mathematical abilities of all America's children is desperately needed (Caverly & MacDonald, 1999; Mulcahy, 2001; Foshay & Perez, 2002). Some current legislation even creates consequences for schools that do not make adequate yearly progress (AYP) in math or other core subject areas (Silberman, 2003). This new law also requires that teachers differentiate and individualize the curriculum to meet the needs of all students, especially low ability students (Cawley & Foley, 2003). The stakes are tremendous, so parents, teachers, and school leaders are taking the failure of America's math students seriously.

As asserted by the NCTM (Butler, Hudson, & Miller, 2006), to consistently make adequate yearly progress, students will need "consistent access to high-quality mathematics instruction" (NCTM, 2000, p. 371). However, this type of reform will take great effort and a focus on student learning at the earliest grades (Ahlgren & Rutherford, 1993). Fortunately, most agree reform in mathematics is critical. Unfortunately, many cannot agree on what type of reform would be best (Butler, Hudson, & Miller, 2006; Lappen, 2001; Landel & Nelson, 2007). Time and effort, trial and error, and research and development will help leaders determine the best course of action to take.

Although various reasons for America's poor performance in mathematics have been proposed, some researchers hypothesize the answer lies with how American teachers instruct their students (Ding, Richardson, & Song, 2006; Gagnon & Maccini, 2007). Mishra (2005) offered three potential areas in which the US could improve instruction including: (a) introducing new content, (b) practicing new content, and (c) reviewing old content. For example, the well-known TIMMS (2003) study documented that US teachers utilized over 50% of their class time, considered to be too much time, reviewing. NCTM (2000) acknowledged this disproportionate emphasis on review and strongly encouraged teachers to review only when scaffolding for new learning.

Top-performing countries spend much less time reviewing math content and more time in other areas. Reviewing is much different than learning for understanding. The latter is recommended by the most current NCTM (2000) standards. Whereas reviewing is considered a cursory re-teaching of content taught previously, learning for understanding deals much more with mastery of a particular concept or set of skills. Either way, the facts are simple; math is often hard to teach and often hard to learn, and how a teacher addresses introduction of content, practicing content, and reviewing content can make the difference (Mann, 2006; Tillman, 2001).

Purpose of the Study

The purpose of this study was to determine the math achievement, behavior, and perceived math ability outcomes of 4th-grade students following participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to the math achievement, behavior, and perceived math ability outcomes of 4th-grade students receiving inquiry-based, hands-on math instruction alone.

The study analyzed beginning of the school year pretest data compared to ending of the school year posttest data, to determine improvement in student outcomes over time and posttest compared to posttest math achievement, behavior, and perceived math ability outcomes data following 4th-grade students' completion of inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to the math achievement, behavior, and perceived math ability outcomes of 4th-grade students receiving inquiry-based, hands-on math instruction alone, to determine independent variable effectiveness.

Research Questions

The following pretest-posttest research questions were used to analyze student participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone measuring norm-referenced math outcomes.

Overarching Pretest-Posttest Math Achievement Research Question # 1: Do students who participate in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction lose, maintain, or improve their beginning 4th-grade compared to ending 4th-grade Iowa Test of Basic Skills (ITBS) math achievement Normal Curve Equivalent (NCE) scores for (a) problem solving/data analysis, (b) concepts/estimation, (c) math total, and (d) math computation subtests?

Sub-Question 1a. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE problem solving/data analysis achievement scores, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Sub-Question 1b. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE concepts/estimation achievement scores, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Sub-Question 1c. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE math total achievement scores, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Sub-Question 1d. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE math computation achievement scores, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Overarching Pretest-Posttest Math Achievement Research Question #2: Do students who participate in inquiry-based, hands-on math instruction alone lose, maintain, or improve their beginning 4th-grade compared to ending 4th-grade ITBS math achievement NCE for (a) problem solving/data analysis, (b) concepts/estimation, (c) math total, and (d) math computation subtests?

Sub-Question 2a. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE problem solving/data analysis achievement scores, after completing the inquiry-based, hands-on math instruction alone school experience?

Sub-Question 2b. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE concepts/estimation achievement scores, after completing the inquiry-based, hands-on math instruction alone school experience?

Sub-Question 2c. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE math total achievement scores, after completing the inquiry-based, hands-on math instruction alone school experience?

Sub-Question 2d. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE math computation achievement scores, after completing the inquiry-based, hands-on math instruction alone school experience?

The following posttest-posttest research questions were used to analyze student participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone measuring norm-referenced math outcomes.

Overarching Posttest-Posttest Norm-Referenced Achievement Research Question #3: Do students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone have congruent or different end of school year NRT math scores, as measured by the ITBS math achievement NCE for (a) problem solving/data analysis, (b) concepts/estimation, (c) math total, and (d) math computation subtests?

Sub-Question 3a. Are NRT NCE scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone, as measured by the ITBS math achievement subtest for problem solving/data analysis?

Sub-Question 3b. Are NRT NCE scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone, as measured by the ITBS math achievement subtest for concepts/estimation?

Sub-Question 3c. Are NRT NCE scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone, as measured by the ITBS math achievement subtest for math total?

Sub-Question 3d. Are NRT NCE scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone, as measured by the ITBS math achievement subtest for math computation?

The following pretest-posttest research questions were used to analyze student participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone measuring criterion-referenced math outcomes.

Overarching Pretest-Posttest Criterion-Referenced Research Question #4: Do students who participate in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction lose, maintain, or improve their beginning 4th-grade compared to ending 4th-grade math achievement scores, as measured by the research school district's criterion-referenced test (CRT) End of the Year Math Test (EOYMT)?

Sub-Question 4a. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade math achievement scores, as measured by the research school district's CRT EOYMT, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Overarching Pretest-Posttest Criterion-Referenced Research Question #5: Do students who participate in inquiry-based, hands-on math instruction alone lose, maintain, or improve their beginning 4th-grade compared to ending 4th-grade math achievement scores, as measured by the research school district's CRT EOYMT?

Sub-Question 5a. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade math achievement scores, as measured by the research school district's CRT EOYMT, after completing the inquiry-based, hands-on math instruction alone school experience?

The following posttest-posttest research questions were used to analyze student participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone measuring CRT math outcomes.

Overarching Posttest-Posttest Criterion-Referenced Achievement Research Question #6: Do students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to students who participated in inquiry-based, hands-on math instruction alone have congruent or different end of school year CRT math scores, as measured by the CRT EOYMT?

Sub-Question 6a. Are scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone, as measured by the CRT EOYMT?

Overarching Posttest-Posttest Criterion-Referenced Test Math Achievement Research Question #7. Do students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction have observed CRT math score improvement frequencies that are the same as for those students who participated in inquiry-based, hands-on math instruction alone, as measured by the CRT EOYMT?

Sub-Question 7a. Are lose, maintain, or improve observed frequencies for the CRT EOYMT scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone, as measured by the CRT EOYMT?

The following pretest-posttest research questions were used to analyze student participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone measuring behavior outcomes.

Overarching Pretest-Posttest Behavior Research Question #8: Do students who participate in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction lose, maintain, or improve their beginning 4th-grade compared to ending 4th-grade behavior outcomes for (a) absences, (b) tardies, and (c) discipline referrals?

Sub-Question 8a. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade absences, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Sub-Question 8b. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade tardies, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Sub-Question 8c. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade discipline referrals, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Overarching Pretest-Posttest Behavior Research Question #9: Do students who participate in inquiry-based, hands-on math instruction alone lose, maintain, or improve their beginning 4th-grade compared to ending 4th-grade behavior outcomes for (a) absences, (b) tardies, and (c) discipline referrals?

Sub-Question 9a. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade absences, after completing the inquiry-based, hands-on math instruction alone school experience?

Sub-Question 9b. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade tardies, after completing the inquiry-based, hands-on math instruction alone school experience?

Sub-Question 9c. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade discipline referrals, after completing the inquiry-based, hands-on math instruction alone school experience?

The following posttest-posttest research questions were used to analyze student participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone measuring behavior outcomes.

Overarching Posttest-Posttest Behavior Research Question #10: Do students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to students who participated in inquiry-based, hands-on math instruction alone have congruent or different end of school year behavior outcome data for (a) absences, (b) tardies, and (c) discipline referrals?

Sub-Question 10a. Are behavior outcome scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone, as measured by the number of students' absences?

Sub-Question 10b. Are behavior outcome scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone, as measured by the number of students' tardies?

Sub-Question 10c. Are behavior outcome scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone, as measured by the number of students' discipline referrals?

The following posttest-posttest research questions were used to analyze student participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone measuring perceptions of math ability.

Overarching Posttest-Posttest Student Perceptions of Math Ability Research Question #11: Do students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to students who participated in inquiry-based, hands-on math instruction alone have congruent or different end of school year perceptions of math ability, as measured by the *Perception of Ability Scale for Students* (PASS)?

Sub-Question 11a. Are the end of the school year perceptions of math ability scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone, as measured by the PASS?

Definitions of Terms

Behavioral data. Behavioral data includes attendance, tardy, and discipline referral information for each participant. These three dependent measures are readily available in the school records, as entered into the Schools Administrative Student Information (SASI) system.

Computer-assisted instruction. Computer-assisted instruction is a type of instruction in which the computer and learner interact in sequence. This usually is done through a question—answer format, with the computer adapting the educational content based on the way a student responds to a particular question. Correct answers by the student results in a learning path that has the computer increase the difficulty of the particular concept or a change in the content. Wrong answers by the student results in a learning path that has the computer decrease the difficulty of the particular concept, change the content, or require the student to complete a tutorial that explains how to arrive at the correct answer (Davis, Leonard, & Sidler, 2005; Cordon & Day, 1993; Dimino, 2007; Edmonds & Li, 2005; Murray & McPherson, 2006).

Differentiated instruction. Differentiated instruction is a teaching theory grounded in the belief that all students are not the same and therefore have diverse instructional needs (Broderick, Mehta-Parekh, & Reid, 2005; Hoover & Patton, 2004). Various aspects of their learning are eliminated, decreased, increased, adapted, or extended based on their varying instructional needs (Hall, 2002). Teachers value and recognize each student's range of background knowledge and other learning factors such as readiness, language, learning preferences, and interests by planning and delivering instruction that takes into account content, process, product, environment, and assessment (Winebrenner, 2001).

Discipline referral information. All discipline referral information will be limited to written referrals to the principal's office, as entered into SASI.

Investigations Math Program. The Investigations math program is a K-5 curriculum, which is less traditional in its approach and is based on the NCTM standards (National Science Foundation, 2007). The Investigations math program is organized around an inquiry-based model that promotes a self-discovery approach to learning. The program also promotes math communication and depth of understanding for math concepts for students (Goodrow, 2007; Russell, 2007). The program is not directly correlated with standardized tests.

Iowa Test of Basic Skills (ITBS). The ITBS, a norm referenced, standardized achievement test was designed to provide information about individual student competence in the basic school subject-matter areas. The authors state three main purposes of the test: (1) to obtain information for supporting instructional decisions, (2) to report individual progress to students and parents, and (3) to evaluate the progress of groups of students. Mathematics subtests measures student understanding of basic math concepts including number properties and operations, geometry, measurement, and problem solving (Salvia & Ysseldyke, 2004).

National Council of Teachers of Mathematics (NCTM). NCTM is a nonprofit education association founded, in 1920, to help improve the teaching and learning of mathematics. NCTM is the world's largest mathematics education organization (available from www.nctm.org).

Normal Curve Equivalent (NCE). NCE are standard scores with a mean equal to 100 and a standard deviation equal to 21.06 (Salvia & Ysseldyke, 2004).

PassKey: A Prescriptive Learning System. PassKey is a web-based, computer-assisted, and interactive computer software program that provides research-based instruction, correlates to national and state standards, and aids students of all abilities learn a variety of subjects, including math. It is aligned with the ITBS (available from www.passkeylearning.com).

Schools Administrative Student Information (SASI). SASI is a published software program designed to help teachers and administrators keep track of student personal information, grades, absences, tardies, discipline referrals, and other pertinent school records. The program replaces much of the information that has been traditionally recorded on a student's cumulative folder, only the information is now stored electronically creating a paper-less system.

Scott Foresman-Addison Wesley (SFAW) Math Program. The SFAW curriculum is a K-6 math program and includes all of the components of a traditional math program (Barnett et al., 2001). The SFAW math program is a combination of traditional and contemporary approaches that are based on the standards set forth by the National Council of Teachers of Mathematics (NCTM; 2000). It is also aligned to many state standards, and various achievement tests, including the ITBS (available from www.scottforesman.com).

Standard Math Program. The Standard math program is two separate math curriculums that have been fused together to create one new comprehensive program. The two components include the SFAW and Investigations math programs.

Web-based instruction. Web-based instruction allows students to access content via the internet. This approach is popular because installing initial software or upgrading to newer versions of software can be done in an instant through the internet, rather than at individual computer workstations (DeFranco, 2005; Carter, Gardner, Schweder, & Wissick, 2003; Engelbrecht & Harding, 2005; Kanuka, 2003;). Although each web page is technically sent to the user individually, the continual sequence of the pages appears to the user as being interactive, regardless of access point throughout the world-wide-web (Hollowman & Warren, 2005).

Assumptions

The study has several strong features including (a) all students participating in the study attended neighboring schools within the same school district; (b) all teachers implemented the same district-approved math curriculum and assessments; (c) teachers were trained to specifically teach the web-based program PassKey and the Standard math program; (d) teachers dedicated one class period per week (45 minutes) for 20 weeks to the web-based program, PassKey; (e) students received the Standard math program all other math class periods; (f) students had equal access to all materials and resources within the school district; and (g) teacher expectations for school-wide student behavior was well-defined and consistently administered. Finally, (h) participating teachers received on-going administrative support through classroom observations and reflective conversations throughout the process.

Delimitations of the Study

This study will be delimited to 4th-grade students enrolled in two urban Midwestern elementary schools and the achievement, behavior, and math perceptions data collected during the spring of 2006 and spring of 2007. Fourth-grade students were required to participate in the research school district's annual testing program each school year, which includes the administration of the Iowa Test of Basic Skills, a norm-referenced achievement test and the End of Year Math Test criterion-referenced measure. Also, routinely collected behavior data and perceptions of math ability data were utilized.

Limitations of the Study

This exploratory study was confined to four 4th-grade classes at two elementary schools during one school year and consisted of two independent research arms. The first arm was a naturally formed group of students (*n* = 19) participating in Standard math instruction used in combination with PassKey math instruction (inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction). The second arm was a randomly selected group of students (*n* = 19) participating in Standard math instruction only (inquiry-based, hands-on math instruction alone). While the two schools were matched for student SES and teacher training and support, the findings could be skewed given the studies small number of participants.

Significance of the Study

This study contributes to educational research on computer-assisted instruction and web-based approaches to teaching math. It also adds to the development of strategies in teaching mathematics, standard practice, and policy development. Finally, the study is of significant interest to the curriculum developers of the PassKey web-based math program, as well as to the publisher Scott Foresman-Addison Wesley.

Contribution to Research

After reviewing the current research on computer-assisted instruction and web-based programs, it is evident that little research has been done on specific web-based programs. There is research available on the effects technology has on education, but the researchers rarely make major attempts to control for variables, and many times the research is only anecdotal in nature, using a pre-posttest design. These facts are particularly true when it comes to studying web-based programs.

Another web-based, computer-assisted program, PLATO (2003), was examined, but this study was qualitative and did not yield statistically derived inferential pretest-posttest results. Also, this study evaluated the math performance of junior high school students, not students at the elementary level. Studies of PassKey, the web-based, computer-assisted program, utilized in the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction research arm of this study has also been informally evaluated using a pretest-posttest research design. In addition, no direct comparison to other math program standards of care or best practices has been conducted. Moreover, in the aforementioned publisher studies, no attempt was made to control for intervening variables, such as equalized teacher training, which could produce confounded results (PassKey, 2000).

Contribution to Practice

The findings of this study can help administrators make informed decisions, as they consider and choose computer-assisted instruction or web-based approaches to teaching core subject areas in the future, especially math.

Contribution to Policy

This study was initiated by a concern some administrators and curriculum developers had that all students improve their math competence. Current grant restrictions and practice dictate that students in junior high and senior high school could exclusively use PLATO, another CAI program, and only gifted math students could access PassKey. These two practices are contrary to the requirement that all students improve their math competence, as well as, possible inequities with access to quality curriculum when it comes to CAI. This study can help influence policy and promote a change in practice, when looking at the critical areas of equity for all students and access to the best math curriculums (NCTM, 2005).

Organization of the Study

Chapter 1 includes the purpose of the study, the research questions, the limitations and delimitations, the assumptions, the significance of the study, and how the study is organized. Chapter 2 includes a review of the current literature on the topics of: inquiry-based math instruction, self-paced math instruction, web-based math instruction, technology-based math instruction, hands-on math instruction, differentiating curriculum and instruction, instructional standards, contemporary math instruction, and improved math problem solving instruction. Chapter 3 describes the participants, the procedures to be followed, the research design, the independent and dependent variables, the dependent measures, the research questions, the data collection techniques, the statistical tests to be conducted, and the participating sites. Chapter 4 reports the research findings, including data analysis, tables, descriptive statistics and inferential statistics. Chapter 5 provides conclusions and a discussion of the research findings.

CHAPTER TWO

Review of the Literature

Inquiry-Based Instruction

There are three areas proposed in which the US can improve math instruction: (a) introducing new math content, (b) practicing new math content, and (c) reviewing previously taught math content (Mishra, 2005).

Introducing new math content. Introducing new math content is an area where inquiry-based math instruction should be a critical part of the improvement process, primarily because the approach allows teachers to do a lot less telling and a lot more questioning (Rogers, 2002). Although teachers do teach directly during critical points in the lesson, they also spend much of their time and efforts orchestrating the lesson in ways that help students discover and develop their own understanding of the concepts, by varying their instructional approaches (Bush, 2006; Gagnon & Maccini, 2007). This inquiry approach is very effective because it supports a problem-solving process that allows students to utilize deeper levels of understanding beyond what traditional approaches have accomplished in the past (Goodrow, 2007; NCTM, 2000).

As mentioned previously, the teacher aids students during teachable moments and at other strategically placed points during the lessons, however, much of the depth of learning is actually a direct result of students own struggles within particular concepts (National Science Foundation, 2007). Depth of understanding flows from activities that the teachers organize and that the students experience, as the students try to make their own sense of the mathematical world around them (Fuller, 2001).

One author described the inquiry approach as one in which students do, rather than one in which students have something done to them (Berlin & Hillen, 1994). This is just another reason why students participating in the inquiry process are more active than passive and more reflective than random in their thinking. Although the learning process is much more extensive, in terms of time it takes to plan and complete lessons, teachers tend to strongly support the process, due to the positive results it produces (Fuller, 2001). Cognitive, affective, and social benefits of an inquiry-based approach to teaching have also been documented (Berlin & Hillen, 1994).

Practicing new math content. Practicing new math content, or self-paced instruction, is a second area in which the US can improve its mathematics instruction. Allowing students time to work independently on individualized content that does not repeat over and over again (Lindquist, 2001), even for as short as 10 weeks, has shown to help students make gains in the area of math (Irish, 2002; NCTM, 2000; Tillman, 2001). Computer-Assisted Instruction (CAI) has tapped into this research knowledge, by structuring lessons so that individual students can solve problems at their own pace and receive immediate feedback--both important pieces of a quality learning program (Ding, Kulm, Li, & Piccolo, 2007; Galbraith & Jones, 2006).

The individualized, self-paced nature of CAI, as well as, the immediate feedback it provides, has demonstrated that CAI has the potential to improve math knowledge and high stakes test scores (Harlacher, Merrell, & Roberts, 2006; Edmonds & Li, 2005; Jones, Palmer, Reid, & Whitlock, 1973; Smith, 1973). Allowing students to work at their own pace, means the curriculum can be personalized to each individual's unique learner profile, making it a powerful tool to help improve student math performance.

Reviewing previously taught math content. Educators have been under great pressure by reform critics to discover new ways to improve math teaching (Ahlgren & Rutherford, 1993; Gagnon & Maccini, 2007; PLATO, Technical Paper #4, 2003). How often and how long teachers review content was listed as one area that the US could improve math instruction (Mishra, 2005). Since web-based programs take into account what students already know, using these systems could decrease the tendency teachers have of spending unnecessary amounts of time reviewing (Plato & Quinn, 2003).

The benefit of aligning NCTM (2000) and other math standards with curriculum, instruction, and assessment has been debated and supported (Clune, 1998; Hoover & Patton, 2004; Rennert-Ariev & Valli, 2002). In fact, some advocate that comprehensive school reform and school improvement may need to center around web-based programs, because of their major focus on curriculum alignment with the standards and since the alignment between instruction and assessment is considered to be an essential component of American progress in math instruction (Galbraith & Jones, 2006; NCTM, 2000; PLATO, Technical Paper #14, 2003).

While there is ample anecdotal evidence supporting the use of web-based mathematics programs, few structured research studies on the instructional effectiveness of web-based programs have been conducted (Engelbrecht & Harding, 2005; Hong, Stewart, & Strudler, 2004; Stoik, 2001; Duggan, Husman, Pennington, & Wadsworth, 2007), and some studies have shown mixed results (Bielefeldt, 2005; Gunter & Scheetz, 2004; Burkette & Kariuki, 2007; Mishra, 2005).

Whereas some researchers have found significant differences for web-based programs (Whittager, 2005), others have not (Boris & Reisetter, 2004), and at least one study showed negative results (Bishop & Slagter van Tryon, 2006). This is why more research is needed in the area of web-based instruction (Hoskins & Van Hooff, 2005).

In the last ten years, since the growing use of web-based programs (DeFranco, 2005; Carter, Gardner, Schweder, & Wissick, 2003; Engelbrecht & Harding, 2005; Kanuka, 2003) there has been a consistent call for more experimental research in this area (Boris & Reisetter, 2004). Efforts related to improving math instruction through technology goes back decades (Hart, Kellar, & Martin, 2001), and even though a lack of research is evident, web-based instruction has actually become the instruction model of choice in some cases, by replacing potentially outdated, traditional classroom instruction (Summers, Waigandt, & Whittaker, 2005; Duggan, Husman, Pennington, & Wadsworth, 2007).

Technology, in the form of web-based programs, may contribute to productive reforms in the US and make a noticeable difference in raising math achievement and test scores (Chernish, DeFranco, Dooley, & Lindner, 2005; NCTM, 2003; PLATO, Technical Paper #2, 2003). Some go so far as to claim that implementing web-based programs could singlehandedly help the US progress significantly (Bielefeldt, 2005; Kulik, 2003). For instance, Kulik (2003) and others (PLATO, Technical Paper #5, 2003) report that technology was the key factor that helped make the difference in many studies completed during the 1960s, 1970s, and 1980s. This is why some promote that it is time to replicate studies in this promising and critical area of reform (PLATO, Technical Paper #1, 1994), particularly for web-based instruction and in the area of math (Engelbrecht and Harding, 2005). The time is viewed as critical for at least two reasons: (a) interest in web-based learning has hit an all time high (Hoskins & Van Hooff, 2005; Conrad & Kanuka, 2003; Reilly, 2004) and (b) web-based programs are available to internet users all over the world (Hollowman & Warren, 2005).

Some researchers would like to see a qualitative look at when and why teachers implement technology and use web-based instruction (Bishop & Slagter van Tryon, 2006). Other researchers want to know if web-based programs harm rather than help students when learning math (Lavooy, Newlin, & Wang, 2005). Some researchers (Bottge, Rueda, Serlin, Hung, & Min Kwon, 2007) are hopeful, but in general, most educators agree that more research must be done (Berk & Martin, 2001). This is because more research will help educators determine potential solutions for the constantly changing problem of how to best serve US students, so they can keep up with an increasingly competitive world market based on improved math knowledge (Lappen, 2001). Research might result in the acceptance of proven math methods, by slowing the pendulum that constantly swings back and forth over the best way to teach math to young children (Silberman, 2003).

Technology-Based Instruction

Technology, specifically Computer-Assisted Instruction (CAI), may be the missing piece many educators have been looking for. In fact, the newest math standards call for the integration of technology (NCTM, 2000, 2003), which has been shown to increase mathematical achievement (Dugdale, Guerrero, & Walker, 2004). Some even believe that advancements in technology may soon become so significant that it may, not only influence the way we teach math or when (Hart, Kellar, & Martin, 2001), but also change what society values within the field of mathematics (Timmerman, 2000).

Fortunately, many of the technology standards cover and overlap with the new math standards (Foster, 2005). Berk and Olson (2001) and others (NCTM, 2003) agree that mathematics without technology is no longer an option but also assert that it is too early to tell the full effects technology will have. An added benefit is that CAI also has the ability to effortlessly scaffold instruction to each student's skill level, thus improving their successful on-task learning time (Davis, Leonard, & Sidler, 2005; Cordon & Day, 1993; Dimino, 2007; Edmonds & Li, 2005; Murray & McPherson, 2006).

CAI has had positive effects on preschoolers to college students and has even been shown to help students with Attention-Deficit Hyperactivity Disorder (DuPaul & Ota, 2002). For instance, Chute and Miksad (1997) found that the cognitive development of preschoolers can be significantly improved, even in as short as an 8-week treatment, by using CAI. First graders have also benefited from CAI math instruction (Capizzi et al., 2006). In fact, instruction incorporating technology at the primary grades is now widespread (Burkette & Kariuki, 2007). Chen and Liu's (2007) research affirmed that CAI can help 4th-graders improve their performance in math. Faux and Fitzpatrick (2002) and others (PLATO Web Learning, 2003) found positive results with 8th-grade math classes. Many colleges are also using CAI as a means to remediation to prepare their students for success (Perin, 2004). Of course, most college math series curriculums now include some type of computer software (Jacobson, 2006; Duggan, Husman, Pennington, & Wadsworth, 2007), and at least one study showed positive effects for college students at risk for failure in math (Edmonds & Li, 2005). CAI has been demonstrated to have positive effects when used with various ages from preschoolers to college students.

In addition, many researchers have demonstrated that technology and CAI can increase motivation in students, their time-on-task, and their level of engagement, as well as their attitude (Chen & Liu, 2007; Dugdale, Guerrero, & Walker, 2004; HSW-YIH SHYU, 1997; Burkette & Kariuki, 2007; Lamb & Johnson, 2006; Smith, 1973; Timmerman, 2000; Duggan, Husman, Pennington, & Wadsworth, 2007). How attitudes influence math acquisition has been known for at least three decades (Fennema & Sherman, 1976). Studies utilizing CAI may help teachers understand students' perceptions and attitudes resulting in improved math lessons for those considered most vulnerable in this important area (Boris & Reisetter, 2004). Many of these students have traditionally performed poorly in math classes and on math assessments (Davis, Leonard, & Sidler, 2005), and they need many supports in order to have a chance at significant growth (Edmonds & Li, 2005).

Past CAI studies, while not definitive, have yielded results that show potential benefits (Davis, Leonard, & Sidler, 2005; Capizzi et al., 2006; Dugdale, Guerrero & Walker, 2004; Jones, Palmer, Reid, & Whitlock, 1973). For example, Park and Slykhuis (2006) compared CAI against a traditional approach to teaching high school physics. Although the mediums, in this case the computer or a traditional textbook, did not seem to matter, the treatment was very limited because it was only implemented for a 2-week to 4-week period, which has been suggested to be too short a time for CAI to register a significant change (Jacobson, 2006). Merrill (2001) claims that in order to register a significant effect, participants need a treatment of 9-weeks or more. Regardless of the time factor, however, more research is needed for educators to determine how much of an impact technology can have in a classroom (Irish, 2002; Jacobson, 2006).

Most educators still believe that regardless of whether teachers use technology or not, they are still considered the key component of a successful instructional math program (Ahlgren & Rutherford, 1993; Buchholz & Cooke, 2005; Hart, Kellar, & Martin, 2001). In fact, as Landel and Nelson (2007) affirm what the teacher does is the essential piece to any math reform. If technology is going to realize its full potential, however, quality professional development for teachers will be necessary, since most do not know how to integrate technology into their math lessons (DeSimone & Parmar, 2006; Dugdale, Guerrero, & Walker, 2004; Timmerman, 2000), and training has been shown to be critical (DeSimone, Phillips, & Smith, 2007).

On the other hand, in terms of implementing technology or not, Hazzan (2003) and others (Edmonds & Li, 2005) remind us there is a third choice: quality teachers who integrate technology effectively. In other words, they believe classrooms should not just have quality teachers or quality technology, but both.

Differentiated Instruction

Differentiated instruction is a teaching theory that is based on the knowledge that all students do not learn alike and that instruction should vary and be adapted to individual and diverse student needs (Broderick, Mehta-Parekh, & Reid, 2005; Hoover & Patton, 2004). Furthermore, differentiated instruction takes into account and recognizes each student's varying background knowledge and other learning factors such as readiness, language, learning preferences, and interests (Hall, 2002).

According to Winebrenner (2001), teachers may plan and deliver instruction that takes into account content, process, product, environment, and assessment, as parts of the process to meet the learning needs of individual students. Winebrenner (2001) also promotes the idea that students provided with differentiated instruction will learn more than others, because they will learn to the greatest extent possible.

Since instruction can be designed for all students, from the lowest to the most gifted student in the same classroom, differentiating the curriculum for learners is a powerful strategy for learning (Bullard, 2005; Rogers, 2002). Difficulty arises, according to Cook (2005), because to differentiate instruction for all students, a teacher must be able to efficiently gather and manage large amounts of data on students in a short period of time, as well as plan lessons based on this information. To synthesize such large amounts of information in short time spans is almost impossible for humans, but computers make the task possible.

Special needs students are consistently some of the most challenging students to teach, and differentiating content, instruction, and assessment for those students can be even more overwhelming for a teacher (Broderick, Mehta-Parekh, & Reid, 2005; Fahsl, 2007; Hoover & Patton, 2004). The use of computers can make such a daunting task feasible for teachers, by simplifying and facilitating data management and thus making the implementation of differentiated instruction, even in diverse classrooms, organized and efficient (Cook, 2005; Cooper, 2005).

Since effective instruction is at least partially based on the ability of teachers to gather data on their students and translate that information into student academic needs, technology has the potential to improve instruction (Boys, et al., 2003), and because students with special needs are being included more and more in the regular classroom, technology may be the best strategy for tackling this challenging task (Fahsl, 2007).

Instructional Standards

Nationally there is intense discussion about implementing the most rigorous math standards with improved math instruction and successful math outcomes for every student (Clune, 1998; Hoover & Patton, 2004), since curriculum is what primarily determines what a teacher will cover over the course of time and theoretically what a student will learn (ARC Center, 2003). This discussion is facilitated by the recognition that the NCTM is including a broad base of math expertise from individuals, learned societies, and state education agencies in the decision making process (Rennert-Ariev & Valli, 2002). A broader view of mathematics, how the discipline of mathematics is tied to other core curriculum areas, and ways to tie mathematics instruction into a student's everyday world are all goals of modern mathematicians, when designing a math curriculum that will prepare students to function in the modern world (Connecting Mathematics Across the Curriculum, 1995).

Current and rigorous math standards. Reform efforts in math education have more recently emphasized creating standards that allow for focus, quality, depth, and high performance of students, while at the same time meeting the increased demands of the public sector of society in the US and abroad (Deatline-Buchman, Griffin, Jitendra, & Sczesniak, 2007). These same researchers also maintain these math standards should center on "inquiry, problem solving, and mathematic connections" (Deatline-Buchman, Griffin, Jitendra, & Sczesniak, 2007, p. 284), concepts also promoted by the NCTM (2000). Contemporary math reformers, regardless of particular theoretical framework or agenda, support the current standards that claim any successful reform effort will require teachers to have students think beyond procedural knowledge and with flexibility and depth (Bottge, Hung, Min Kwon, Rueda, & Serlin, 2007).

Contemporary Math Instruction

Standard math instruction. Traditional approaches to teaching and learning can also be just as effective as individualized and self-paced approaches (Batchelder & Rachal, 2000). Like other areas the results have been mixed and more research is needed. More research will enable educators to establish whether self-paced instruction will help the US improve in the area of practicing new math content (Dugdale, Guerrero, & Walker, 2004).

The Standard math program is, in reality, two separate math curricula that have been fused together to create one comprehensive program. The Scott Foresman-Addison Wesley (Barnett et al., 2001) curriculum is a K-6 math program that includes all of the components of a traditional math program. At the same time, SFAW does present math concepts using strategies that are in-line with current theory, practice, and standards. Like other, modern curriculums of its type, SFAW claims to have found a balance between traditional and contemporary that is still based on the standards set forth by the NCTM, many state standards, and various achievement tests. It is also significant to this study that just as PassKey is correlated with the ITBS so is SFAW.

Investigations math instruction. The second part of the Standard math program, Investigations, is less traditional in its approach. Beginning in 1990, the Investigations math program was actually developed by TERC, a non-profit organization, and was partially funded by the National Science Foundation (Goodrow, 2007). The result was the development of a comprehensive Kindergarten through 5th grade curriculum that had essentially four goals: "(1) To substantially expand the pool of mathematically literate students (2) To offer all students meaningful mathematical problems (3) To emphasize depth in mathematical thinking and (4) To communicate mathematics content and pedagogy to teachers" (Goodrow, 2007, p. 1).

Rather than textbooks being the primary resource for teachers and students, the Investigations math program comes in kits. Depending on the unit or concept that includes lessons related to number, data analysis, and geometry, the kits have enough student and teacher resources, activities, games, and assessments to cover a three to eight week period (available from http://investigations.scottforesman.com). Since the concepts build on one another, and explore specific math strands, units should be taught and completed in a specific order (Goodrow, 2007). Unlike the SFAW curriculum, which uses a more direct teaching approach to concept development, Investigations proposes a self-discovery approach to learning (Goodrow, 2007).

In reality, the Investigations math program is based on an inquiry-based model, giving it a more recent research backing (Goodrow, 2007). The focus is actually placed on the exploratory process that students think through to find answers, rather than the final product, and the belief is that students have a greater depth of math understanding when they are done (Russell, 2007). One goal is to help students understand that there is often more than one way to solve a math problem and that finding the right answer is only one part of what real mathematicians do (NCTM, 2000). Another goal of the Investigations math program is the promotion of student problem solving skills both as individuals and cooperatively, particularly creation of their own strategies and thinking as it relates to mathematical constructs (available from http://investigations.scottforesman.com).

Also promoted by the NCTM (2000), math communication within Investigations supports student use of math concepts and language to develop math problem solving strategies (Cawley & Foley, 2002; NCTM, 2007). Creators of the Investigation math program believe that when students discuss math strategies and their thinking with others a greater depth of understanding can occur, particularly in the area of math problem solving, which is now considered to be paramount to a learner's success with various types of thinking (Xin, 2007).

Researchers have completed specific studies, with more to follow, and reported positive results for Investigations (Mokros, 2000; Berle-Carman, Mokros, O'Neil, & Rubin, 2007; Mokros, Berle-Carman, Mokros, Rubin, & Wright, 1994). Lambdin and Kehle (in press) are in the process of finishing a longitudinal study, based on Investigations, with forthcoming results (Kehle, 2007). Like PassKey, the developers themselves have directed most of the research that has gone into Investigations, but the results have been positive (Simpson, 2004).

Scott Foresman-Addison Wesley (SFAW). The SFAW math program promotes the instructional theory that teachers should directly teach math concepts to students, rather than have students explore math concepts on their own. Math algorithms generally are introduced first, with exploration being somewhat secondary. According to their website, the publishing house, SFAW, strives to be the very best in its field. They also claim to be the world's top publisher of elementary, educational material. SFAW has a long-standing reputation for quality and has published research that shows positive results (available from www.scottforesman.com).

Passkey math instruction. PassKey is an example of a state-of-the-art computer-assisted (CAI) program. PassKey is currently being evaluated as an effective addition to, or perhaps a replacement for, current traditional math methods, since it is aligned to many state standards, linked to many standardized math tests, easy-to-use, focused on individual student needs, and self-paced. (PassKey, 2000).

PassKey literature describes a web-based math program that can raise student math skills, confidence, and test scores. PassKey uses a lesson format that pretests the math concept being taught, provides a tutorial to highlight that specific math concept, provides guided practice to help check for understanding, and administers a posttest for a summative assessment of that particular concept (PassKey, 2000). This format of presentation is in-line with the current NCTM (2000) standards. PassKey also provides lessons that cover multiple grades. PassKey lessons were developed for students in 1st-grade through college. PassKey is also self-paced, another potential benefit because it reduces the amount of time students spend practicing or reviewing material they have already mastered (PassKey, 2000).

Finally, and probably most important for this study, PassKey is correlated with the Iowa Test of Basic Skills (ITBS). In short, PassKey proposes that implementing their program will improve student scores on many standardized tests (PassKey, 1999). PassKey CAI math instruction may change how educators introduce, practice, and review new math content, as recommended by Mishra (2005).

Improved Math Problem Solving Instruction

Because math is now considered a high stakes school subject, educators are focusing much of their efforts on discovering new and improved methods for teaching math (Desimone, Phillips, & Smith, 2007; Kulm, 2007; NCTM, 2006). NCTM (2000) proposes that improved instruction in the area of problem solving is the key to moving the US ahead of other nations in mathematics. Teaching students the depth and breadth of skills needed for math problem solving is both complicated and time consuming, requiring students to be exposed to and struggle with a myriad of word problems across a variety of contexts (Xin, 2007). This is at least part of the reason traditional and current textbooks have not solved the dilemma most teachers face when approaching the difficult task of teaching math problem solving (Deatline-Buchman, Griffin, Jitendra, & Sczesniak, 2007).

Three different approaches to teaching math are used in this study. Scott Foresman-Addison Wesley (SFAW) offers an approach to teaching math problem solving that is more traditional and direct in nature. According to one source, a typical SFAW lesson includes example problems, practice problems, and vocabulary (Mauch & McDermott, 2007). The math program Investigations recommends a different approach to teaching math problem solving that is considered more contemporary, by having students use an inquiry-based strategy that allows them to develop their own understanding and approaches to coming up with a solution to a math problem (Andrew, 2007; Goodrow, 2007). PassKey proposes a third approach to teaching math problem solving. Actually, PassKey follows a similar format to SFAW only the presentation is different, since it is taught by a computer-based tutorial that is accessed online, as a part of what has been referred to as an "instruction-based" system (Ellis, Kennedy, & Oien, 2007, p. 118).

Three Examples of 4th-Grade Math Problem Solving Instruction

SFAW math problem solving instruction. SFAW instructs teachers and students to use a four-step process when solving word problems. The four components and their explanations are: (1) Understand (a) Figure out what you know (b) Figure out what you need to find, (2) Plan (a) Decide how you will find your answer, (3) Solve (a) Find the answer (b) Write your answer, and (4) Look Back (a) Check to see if your answer makes sense (Barnett et al., 2001).

SFAW (2001) also lists nine different problem-solving approaches that students may choose from as strategies, when presented with any problem-solving task. The nine problem solving strategies introduced by teachers are: (1) Use objects/Act it out, (2) Draw a picture, (3) Look for a pattern, (4) Guess and check, (5) Use logical reasoning, (6) Make an organized list, (7) Make a table, (8) Solve a simpler problem, and (9) Work backward. SFAW introduces each problem solving strategy in a separate lesson, about one per chapter, and includes practice problems for that particular strategy so that students can master that precise strategy before moving on. Students are then expected to come back to those strategies, when appropriate and when necessary, by drawing from their newly acquired skills and by choosing the approach that the student is most confident with and is most efficient for that particular problem.

Lesson 9 in Chapter 3 SFAW (2001) presents students with a series of math word problems that require multiple steps to solve. In one example students are presented with information in the following table:

Publishing Website

Hits from North America		*Hits from Oceania*	
Canada	2,485	Australia	2,465
Mexico	10	New Zealand	464
United States	1,199		

Students are also told the following: "Young writers can publish their stories on the World Wide Web. Look at the number of hits on this publishing website. How many more hits came from North America than Australia?" (SFAW, 2001, p. 118). Teachers are instructed to model the four step math problem solving approach (1) Understand, (2) Plan, (3) Solve, and (4) Look Back. After students fully understand the problem by figuring out what they know and what they need to find out, teachers have students come up with a plan to solve the problem. Since the problem is multi-step, the students' plans must include finding the total hits for North America and then comparing that answer to the total hits from Australia. More specifically, students are required to add the number of hits for Canada with the number of hits for Mexico with the number of hits for the United States as displayed here:

Canada	2,485
Mexico	10
United States	+ 1,199
	3,694

Students then must subtract the number of hits in Australia from this total to find the difference between the two as displayed here:

North America	3,694
Australia	- 2,465
	1,229

Finally, students are encouraged to look back to determine if the difference of 1,229 hits makes sense and how they know or can explain why their answer makes sense.

Investigations math problem solving instruction. Investigations uses a different approach to math problem solving. Rather than promote a step-by-step strategy to problem solving, Investigations encourages students to explore the concept of math problem solving through manipulatives, drawing pictures, in-depth thinking, and student conversations, which are all supported and promoted by teachers asking questions rather than providing answers (Russell, 2007). They also promote a cooperative learning approach to problem solving, since this small group format fosters communication and is supported by research (Ding, Kulm, Li, & Piccolo, 2007).

In the Investigations math program, because the problems usually require more depth of thinking and a communication component, the questions are fewer in number than found in the more traditional Scott Foresman-Addison Wesley (SFAW) curriculum. Also, many times the questions are presented as a short series of problems all related somehow to each other. On occasion, Investigations does give students simple suggestions, as seen in the following example: "Solve each problem. You may want to use a 300 Chart to help" (Sunken Ships and Grid Patterns, 2003, p. 181).

The way questions are presented in Investigations as a short series of math problems that are all related can be represented by the 4th-grade examples found on a Practice Page in Sunken Ships and Grid Patterns (2003, p. 181).

1. Two frogs had a race. Hoppy Frog took 10 jumps of 28. Hurry Frog took 5 jumps of 55. Who was ahead? How do you know?
2. In a second race, Hoppy took 9 jumps of 30. Hurry took 7 jumps of 38. Who was ahead? How do you know?

3. In the last race, Hoppy decided to take jumps of 150. She took 1 jump of 150. How many more jumps of 150 did she need to reach 300? How do you know?

These three examples show how the Investigations uses two frogs, Hoppy and Hurry, to encourage students to begin to think about skip counting, repeated addition, multiplication, finding differences, and multiple step math problems. These examples also show how students are required to share their thinking about how they solved the problem. In other words, Investigations not only wants students to get the right answer, but they also believe students should be able to explain how they got their answer, as well as, how they know the answer makes sense, which requires students to think more deeply about the math problem.

PassKey math problem solving instruction. Using a 72 page web-based tutorial, PassKey instructs students to use a six-step process when solving word problems. Along with the six steps, the PassKey problem solving tutorial states that reading for understanding, using logical deductions, and thinking carefully about the problem will help all students be successful math problem solvers. The six components and their explanations from the PassKey website (available from http://www.passkeylearning.com) are as follows:

(Step 1) Identify the question or direction. Decide whether the answer will be estimated or exact.

(Step 2) Pick out the numerical information. Check to see if all measurements are given in the same type of units.

(Step 3) Determine if you have all the information that you need to solve the problem. If you do, skip to Step 5. If not, determine what information is missing, and go to Step 4.

(Step 4) If there is missing information, identify the mathematical operations you will use to find the missing information, and solve for it.

(Step 5) Identify the mathematical operation(s) you will use to solve the problem.

(Step 6) Solve the problem.

The 72 page PassKey Tutorial presents students with a series of math word problems that require multiple steps to solve. In one 4th-grade example, students are presented with the following word problem:

Phil O. Dendron is a serious plant collector. (-a-) He has a large greenhouse with 22 rows of plants. (-b-) There are 45 plants in each row. His wife, Rhonda Dendron, also collects plants. (-c-) She has a smaller greenhouse with 16 rows of plants. (-d-) In each row there are 32 plants. (-e-) How many plants are in the Dendron greenhouses?

The Tutorial helps the students solve the problem, by asking a series of questions and by supplying the logical answers on the click of the mouse. For example, for the problem above the computer restates Step 1 (Identify the question or direction, and decide whether the answer will be estimated or exact) and asks the question, "Which letter is in front of the sentence that contains the question or direction in this problem?" Answer: -e- How many plants are in the Dendron greenhouses? Next, Step 2 (Pick out the numerical information, and check to see if all measurements are given in the same type of units) is repeated and the question, "Which sentences contain numerical information?" Answer: -a- He has a large greenhouse with 22 rows of plants, -b- There are 45 plants in each row, -c- She has a smaller greenhouse with 16 rows of plants, and -d- In each row there are 32 plants. Also, Step 3 (Determine if you have all the information that you need to solve the problem. If you do, skip to Step 5 and if not, determine what information is missing, and go to Step 4) is shown again and the computer states, "We want to find how many plants are in the greenhouses. To answer this, we need to know how many plants are in each greenhouse." It also asks, "Does this problem state how many plants are in each greenhouse?" Answer: Yes. Next, Step 4 (If there is missing information, identify the mathematical operations you will use to find the missing information, and solve for it) is reiterated. Answer: There is no missing information. Also, Step 5 (Identify the mathematical operation(s) you will use to solve the problem) is repeated. Answer: Multiplication and Addition. Finally, Step 6 (Solve the problem) is restated. Answer: 1,502 plants. This is a multi-step math problem. The Tutorial finalizes the math problem by explaining that to get the answer you will need to multiply and add. It displays the following:

STEP 1 - Multiply

$$\begin{array}{r} 22 \\ \times\ \underline{45} \\ 990 \end{array} \qquad \begin{array}{r} 16 \\ \times\ \underline{32} \\ 512 \end{array}$$

STEP 2 — Add

$$\begin{array}{r} 990 \\ +\ \underline{512} \\ 1{,}502 \end{array}$$

PassKey has the following lesson components: Pretest, Tutorial, Guided Practice, Posttest, and the Wrong Answer Review (PassKey, 2000). The Pretest questions students to determine their knowledge of a particular concept. If the student is able to answer most of the questions at the minimum percentage level pre-assigned by the teacher, the student is permitted to bypass the rest of the lesson. If the computer determines the opposite, the student is immediately placed in the Tutorial for that particular math concept. The Tutorial directly teaches the student the concept by using an interactive format in which the student is provided with math problems, questions that probe the students to think about the problems, and the answers, as well as the steps one goes through in order to obtain the correct answer. Two researchers said it most eloquently when they explained, "There is a harmony between the learner and the computer by means of questioning and rejoining the responses" (Imamoglu & Kahveci, 2007, p. 139).

Guided Practice is similar to the Tutorial except the computer provides guidance only for incorrect answers. The computer assumes that correct answers provided by the student equate to correct process. The Posttest is typically about ten questions and tests the student's knowledge of the math concept previously taught in the Tutorial and/or the Guided Practice. One final component of the PassKey lesson regiment is the Wrong Answer Review. This feature of the program can be set ahead of time by the teacher so that after the Posttest all of the test questions, incorrect answers, and correct answers are reviewed one final time to ensure mastery. There are also many teacher reports, so a teacher can check and track individual student progress, improvement, test scores, and math strengths or weaknesses (PassKey Online Guide, available from http://www.passkeylearning.com).

CHAPTER THREE

Research Methods

Participants

Number of participants. There was a maximum of 38 students participating in this study. Approximately 19 students participated in the Standard math program in combination with PassKey (inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction), and about 19 students participated in the Standard math program only (inquiry-based, hands-on math instruction alone). Two groups were naturally formed and two groups were randomly selected, with all participants attending in four different 4th-grade classrooms and in two demographically congruent, neighborhood schools. Both schools have similar socioeconomic levels, with the research school having a free and reduced lunch percentage of 90% for May 2007 and the comparison school documenting an 82% free and reduced lunch rate for that same month.

Two of the 4th—grade classes were within the research school, and the other 4th—grade classes served as comparison groups. Again, these two comparison 4th-grades are housed in another demographically congruent school within the research school district and only used the

Standard math program during the entire study. None of the students in these two comparison classrooms used PassKey, CAI, or any other web-based math programs.

Gender of participants. The gender of the participants was congruent with enrollment patterns in the participating district, where females represent 49.1% and males represent 50.9% of the total enrollment. The total number of females participating in the study was 13. This represents 34% of the total sample. There were 25 males, which represents 66% of the total sample. School 1 has 4 females (21%) and 15 males (79%). School 2 has 9 females (47%) and 10 males (53%).

Age range of participants. The age of the participants ranged from 8 to 10 years old. Each participant was enrolled in the participating district from 2005-2007, completed the 3rd-grade in 2005-2006, and 4th-grade during the 2006-2007 school year.

Racial and ethnic origin of participants. The racial and ethnic, origin ratio was similar to enrollment patterns in the participating district. However, the two sample schools are somewhat more diverse in regards to ethnicity, when compared to the district. Like socioeconomic status, the two sample schools are much more congruent in racial patterns. The current enrollment ethnicity patterns in the participating district were 86.7% Caucasian; 2.9% African-American; 8.8% Hispanic; 0.9% Asian; and 0.7% Native American. For this study there were 29 Caucasian students, representing about 76.3% of the total sample. About 15.8% of the sample was Hispanic. This percentage included 6 students. There were also 2 African-American students, which represented approximately 5.3% of the sample. There was 1 Asian student, who was about 2.6% of the total sample. Finally, there were no Native American students participating in the study.

In terms of the potential samples, the racial make-up for school 1 was as follows: Asian, 1 student (5.2%); African-American, 0 students (0%); Hispanic, 3 students (15.8%); Caucasian, 15 students (78.9%); and Native American, 0 students (0%). The racial make-up of school 2 was as follows: Asian, 0 students (0%); African-American, 2 students (about 10.5%); Hispanic, 3 students (15.8%); Caucasian, 14 students (73.7%); and Native American, 0 students (0%). The final student samples were dependent upon attrition, as well as, the random selection of one of the two groups.

Inclusion criteria of participants. Student participants completed 3rd-grade in the research school district and successfully completed the 3rd-grade math classes, which led to 4th-grade academic promotion for the 2006-2007 school year. Fourth-grade students' end of 3rd-grade Iowa Test of Basic Skills (ITBS) scores and their criterion-referenced end of 3rd-grade, 2005-2006 school year math test (EOYMT) scores served as the study pretest scores. Participants also completed the PASS at the end of the 2006-2007 4th-grade school year.

Method of participant identification. Every effort was taken to include all of the 4th-grade students at both participating schools in the study. This resulted in a total of four 4th-grade sections participating in the study, which included no more than 40 students. All students, regardless of socio-economic status or special education identification, participated in the Standard math program used in combination with PassKey (inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction) or the Standard math program only (inquiry-based, hands-on math instruction alone).

Description of Procedures

The pretest-posttest, two-group comparative survey study design is displayed in the following notation:

Group 1 X_1 0_1 X_2 0_2

Group 2 X_1 0_1 X_3 0_2

Group 1 = Naturally formed 4th-grade group (*n* = 19)

Group 2 = Randomly selected 4th-grade group (*n* = 19)

X_1 = Successful completion of 3rd-grade Inquiry-Based, Hands-On Math Instruction before entering 4th-grade in the research school district

X_2 = Inquiry-Based, Hands-On Math Instruction used in combination with Web-Based, Computer-Assisted math instruction

X_3 = Inquiry-Based, Hands-On Math Instruction alone

0_1 = Pretest (1) Achievement: (a) Iowa Test of Basic Skills (ITBS) Normal Curve Equivalent (NCE) scores, as measured in April of 2006 (*i*) Math Problem Solving/Data Analysis, (ii) Math Concepts/Estimation, (*iii*) Math Total, and (*iv*) Math Computation and (b) District End of the Year Criterion-Referenced Math Test (EOYMT) for 2005-2006 3rd-grade. (2) Behavior: (a) absence data for the 2005-2006 school year 3rd-grade, (b) tardy data for the 2005-2006 school year 3rd-grade, and(c) discipline referral data for the 2005-2006 school year 3rd-grade.

0_2 = Posttest (1) Achievement: (a) ITBS NCE, as measured in April of 2007 (*i*) Math Problem Solving/Data Analysis, (ii) Math Concepts/Estimation, (*iii*) Math Total, and (*iv*) Math Computation, and (b) District EOYMT for 2006-2007 4th-grade. (2) Behavior: (a) absence data for the

2006-2007 school year 4th-grade, (b) tardy data for the 2006-2007 school year 4th-grade, and (c) discipline referral data for the 2006-2007 school year 4th-grade. (3) Perception: Perceived Math Ability Scale (PASS) data collected in May of 2007, at the end of the 4th-grade school year.

Study Procedures

Each 4th-grade student participating in the study completed the Iowa Test of Basic Skills (ITBS) in April of 2006, as well as the End of the Year Math Test (EOYMT) in May of 2006. In addition, each 4th-grader completed a math ability perception scale, the *Perception of Ability Scale for Students (PASS)*, in May of 2007. Next, behavior data, as reflected in discipline referrals recorded into SASI during the 2005-2006 school year, was accessed and placed into a spreadsheet. Finally, attendance and tardy information was gathered from SASI for that same year and was included in the spreadsheet. All of this information was then used as baseline data for comparisons during the retrospective, statistical analysis.

The two teachers implementing PassKey were trained in October of 2006. In order to equalize all training, the two teachers were trained by a PassKey curriculum specialist and trainer. In addition, all four teachers involved in the study had formerly been trained and had implemented the Standard math program, under the guidelines of the district's standards, policies, and procedures. Two of the teachers supplemented the Standard math program with the use of the PassKey math program, and two of the teachers continued their daily use of the Standard math program. The two teachers implementing the inquiry-based, hands-on math program were relatively new teachers, with one in her first year and the other in his second year. The two teachers using the web-based, computer-assisted math program had ten years and six years of teaching experience, respectively. All of the teachers had Bachelor degrees.

One day of initial training time for the two teachers implementing PassKey was provided. Both teachers received a copy of the PassKey training manual and were given sufficient time to review it. This took most of the morning. The afternoon was spent with the PassKey curriculum trainer actually working with the program. Within a few hours and with the help of the trainer, both teachers felt confident enough that they could begin implementing PassKey the following week. They both found the program to be very user friendly.

The building principal provided on-going and additional supports where the program was being coordinated. Similar to the teachers, he had been formally trained in the use of PassKey. He has also used PassKey as a teacher in the classroom. A third support was also included to help ensure the success of the PassKey math program. This support included a central office administrator who was also formally trained in PassKey. He is also familiar with other CAI systems, which he has also used at a classroom level. He is very knowledgeable, particularly in the area of math, and serves as the district, elementary supervisor and curriculum director.

In addition, all three trainers were available to the 4th-grade teachers implementing the two programs, on a continual basis and for the entire length of the program. Finally, the school's media specialist was available on a weekly, as well as, on an as-needed basis for additional support related to technological needs. Each of these supports helped ensure a more successful implementation of the web-based program and fidelity to the program design (Plato & Quinn, 2003).

Two of the teachers took their entire class to the school computer lab once a week for twenty weeks. During that time, students worked on their assigned web-based math program, PassKey, and each session lasted 45 minutes, with under 30 hours being dedicated to the web-based program

(PLATO, Technical Paper #12, 2004). The rest of the time was allotted for teaching math by using the Standard math program. Each of these class periods was also 45 minutes long, and one math period was taught each school day, which resulted in four 45-minute Standard math sessions and one 45-minute PassKey math period every week for two of the classrooms.

In contrast, students involved only in the Standard math program, the other two classrooms, used the Standard math program five days each week. The math periods also lasted 45 minutes, for a total of five Standard math lessons per week.

Each 4th-grade student participating in the programs also completed the Iowa Test of Basic Skills (ITBS) in April of 2007. In addition, they took a criterion-referenced test (CRT), the EOYMT, in May of 2007. Also, each participant completed a math ability perception survey, PASS, in May of 2007. Next, behavior data from SASI was collected for the 2006-2007 school year on each participant. Finally, attendance data was tabulated for the 4th-grade students in 2006-2007. All of this information was then added to the spreadsheet created previously for the baseline data. The data was then imported into the computer software, so that the appropriate statistical tests could be run.

Independent Variable Descriptions

PassKey: A Prescriptive Learning System. According to their website, PassKey proposes to be: aligned to many state standards, linked to many standardized tests, easy-to-use, focused on individual student needs, self-paced, and research-based (available from www.passkeylearning.com). In addition, PassKey claims to be a web-based math program that will raise student math skills, confidence, and test scores (PassKey, 2000). The designers of PassKey have also created at least three other important functions.

First, they use a lesson format that pretests the concept being taught, provides a tutorial to highlight that specific concept, presents guided practice to help check for understanding, and gives a posttest for a summative assessment of that particular concept (PassKey, 1999). Second, PassKey provides lessons that span multiple grade levels. PassKey lessons begin as early as 1st-grade and can include college level lessons, as well (PassKey, 2000). Finally, and probably most important for this study, PassKey claims to correlate with the Iowa Test of Basic Skills (PassKey, 1999). In other words, PassKey claims that using their product can raise scores on this particular standardized test.

Standard math program. Scott Foresman-Addison Wesley (SFAW) and Investigations. The Standard math program combines a more traditional approach to teaching math, as presented in the SFAW math curriculum with the more modern Investigations math curriculum. The combination of these two approaches proves to be a solid, core math program that focuses on the best of both curriculums. SFAW, although more traditional, still presents math concepts within modern theories and practices. SFAW attempts to balance traditional and contemporary approaches to teaching math. In fact, the modern SFAW curriculum imbeds itself in the vision of the National Council of Teachers of Mathematics (NCTM), as presented in their most recent standards (NCTM, 2000). Of particular importance for this study is the claim that the SFAW curriculum is also correlated with the ITBS.

Investigations, a contemporary way of teaching math, is also based on the most recent NCTM (2000) standards. Unlike SFAW, the Investigations math program comes in hands-on kits. Where SFAW relies on a textbook as its main resource, Investigations provides teachers with resources that includes, but is not limited to, games, activities, teacher resources, and assessments for the units of math study.

With a more contemporary view on math instruction, the Investigations math program uses an inquiry-based approach that promotes student self-discovery and depth of understanding (Andrew, 2007). Exploration of math concepts by students is encouraged, and teachers are asked to value both math vocabulary and math communication. Also, students are encouraged to reflect on their discoveries and communicate that information to others in a written or an oral manner. As a result, students using the Investigations curriculum develop a depth of understanding that can often translate across contexts, regardless of the assessment. SFAW also propose that when math concepts are imbedded in a student's understanding, they do well on both NRT's and CRT's (available from www.scottforesman.com).

Dependent Measures

The research questions for this study focused on the dependent variables of achievement, behavior, and perceptions of math ability. The first of these, achievement, was analyzed using the following dependent measures: (a) Norm-Referenced Test (NRT) scores from the Iowa Test of Basic Skills (ITBS), which will include the Normal Curve Equivalent (NCE) scores for math and (b)

Criterion-Referenced Test (CRT) scores from the district End of the Year Math Test (EOYMT). This achievement information was collected retrospectively from the students' 3rd-grade and 4th-grade data.

The second dependent measure category, behavior, was also collected retrospectively. It included the 3rd-grade and 4th-grade information stored in SASI. Specifically, the dependent behavior measures were attendance, tardies, and discipline referral data for each student participating in the study. Again, this information was obtained from SASI, since both schools involved in the study use SASI to record all behavioral data.

The third dependent measure was students' perceptions towards their math ability. Like the other two categories, math perception data was collected retrospectively. Math perception was measured through a post-survey. The 4th-grade students in both participating schools completed the *Perception of Ability Scale for Students*, PASS, in May of 2007.

Using Cronbach's coefficient alpha the authors of PASS report positive reliability results. In fact, they report full-scale alphas ranging from .91 to .93, depending on the sample, and alphas greater than .75 for most of the subscales. Various types of validity are also reported including content, criterion, and construct. In addition, according to two reviewers, Harwell and Subkoviak, as presented in The Twelfth Mental Measurements Yearbook (1995), the PASS is strong in both reliability and validity.

Purpose of the Study

The purpose of this study was to determine the math achievement, behavior, and perceived math ability outcomes of 4th-grade students following participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to the math achievement, behavior, and perceived math ability outcomes of 4th-grade students receiving inquiry-based, hands-on math instruction alone.

The study analyzed beginning of the school year pretest compared to ending of the school year posttest data, to determine improvement in student outcomes over time and posttest compared to posttest math achievement, behavior, and perceived math ability outcomes data following 4th-grade students' completion of inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to the math achievement, behavior, and perceived math ability outcomes of 4th-grade students receiving inquiry-based, hands-on math instruction alone to determine independent variable effectiveness.

Research Questions, Sub-Questions, and Data Analysis

The following pretest-posttest research questions were used to analyze student participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone measuring norm-referenced math outcomes.

Overarching Pretest-Posttest Math Achievement Research Question # 1: Do students who participate in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction lose, maintain, or improve their beginning 4th-grade compared to ending 4th-grade Iowa Test of Basic Skills (ITBS) math achievement Normal Curve Equivalent (NCE) scores for (a) problem solving/data analysis, (b) concepts/estimation, (c) math total, and (d) math computation subtests?

Sub-Question 1a. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE problem solving/data analysis achievement scores, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Sub-Question 1b. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE concepts/estimation achievement scores, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Sub-Question 1c. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE math total achievement scores, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Sub-Question 1d. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE math computation achievement scores, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Research Sub-Questions #1a, 1b, 1c, and 1d were analyzed using dependent *t* tests to examine the significance of the difference between students' beginning 4th-grade compared to ending 4th-grade NRT NCE math achievement scores following inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction. Because multiple statistical tests were conducted, a one-tailed .01 alpha level was employed to help control for Type 1 errors. Means and standard deviations were displayed on tables.

Overarching Pretest-Posttest Math Achievement Research Question #2: Do students who participate in inquiry-based, hands-on math instruction alone lose, maintain, or improve their beginning 4th-grade compared to ending 4th-grade ITBS math achievement NCE for (a) problem solving/data analysis, (b) concepts/estimation, (c) math total, and (d) math computation subtests?

Sub-Question 2a. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE problem solving/data analysis achievement scores, after completing the inquiry-based, hands-on math instruction alone school experience?

Sub-Question 2b. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE concepts/estimation achievement scores, after completing the inquiry-based, hands-on math instruction alone school experience?

Sub-Question 2c. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE math total achievement scores, after completing the inquiry-based, hands-on math instruction alone school experience?

Sub-Question 2d. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade NCE math computation achievement scores, after completing the inquiry-based, hands-on math instruction alone school experience?

Research Sub-Questions #2a, 2b, 2c, and 2d were analyzed using dependent *t* tests to examine the significance of the difference between students' beginning 4th-grade compared to ending 4th-grade NRT NCE math achievement scores following inquiry-based, hands-on math instruction alone. Because multiple statistical tests were conducted, a one-tailed .01 alpha level was employed to help control for Type 1 errors. Means and standard deviations were displayed on tables.

The following posttest-posttest research questions were used to analyze student participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone measuring norm-referenced math outcomes.

Overarching Posttest-Posttest Norm-Referenced Achievement Research Question #3: Do students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone have congruent or different end of school year NRT math scores, as measured by the ITBS math achievement NCE for (a) problem solving/data analysis, (b) concepts/estimation, (c) math total, and (d) math computation subtests?

Sub-Question 3a. Are NRT NCE scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone, as measured by the ITBS math achievement subtest for problem solving/data analysis?

Sub-Question 3b. Are NRT NCE scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone, as measured by the ITBS math achievement subtest for concepts/estimation?

Sub-Question 3c. Are NRT NCE scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone, as measured by the ITBS math achievement subtest for math total?

Sub-Question 3d. Are NRT NCE scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone, as measured by the ITBS math achievement subtest for math computation?

Research Sub-Questions #3a, 3b, 3c, and 3d were analyzed using independent *t* tests to examine the significance of the difference between students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and students who participated in inquiry-based, hands-on math instruction alone ending 4th-grade compared to ending 4th-grade NRT NCE math achievement scores. Because multiple statistical tests were conducted, a one-tailed .01 alpha level was employed to help control for Type 1 errors. Means and standard deviations were displayed on tables.

The following pretest-posttest research questions were used to analyze student participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone measuring criterion-referenced math outcomes.

Overarching Pretest-Posttest Criterion-Referenced Research Question #4: Do students who participate in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction lose, maintain, or improve their beginning 4th-grade compared to ending 4th-grade math achievement scores, as measured by the research school district's criterion-referenced test (CRT) End of the Year Math Test (EOYMT)?

Sub-Question 4a. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade math achievement scores, as measured by the research school district's CRT EOYMT, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Research Sub-Question #4a was analyzed using dependent *t* tests to examine the significance of the difference between students' beginning 4th-grade compared to ending 4th-grade CRT EOYMT math achievement scores following inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction. Because multiple statistical tests were conducted, a one-tailed .01 alpha level was employed to help control for Type 1 errors. Means and standard deviations were displayed on tables.

Overarching Pretest-Posttest Criterion-Referenced Research Question #5: Do students who participate in inquiry-based, hands-on math instruction alone lose, maintain, or improve their beginning 4th-grade compared to ending 4th-grade math achievement scores, as measured by the research school district's CRT EOYMT?

Sub-Question 5a. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade math achievement scores, as measured by the research school district's CRT EOYMT, after completing the inquiry-based, hands-on math instruction alone school experience?

Research Sub-Question #5a was analyzed using dependent *t* tests to examine the significance of the difference between students' beginning 4th-grade compared to ending 4th-grade CRT EOYMT math achievement scores following inquiry-based, hands-on math instruction alone. Because multiple statistical tests will be conducted, a one-tailed .01 alpha level was employed to help control for Type 1 errors. Means and standard deviations were displayed on tables.

The following posttest-posttest research questions were used to analyze student participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone measuring CRT math outcomes.

Overarching Posttest-Posttest Criterion-Referenced Achievement Research Question #6: Do students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to students who participated in inquiry-based, hands-on math instruction alone have congruent or different end of school year CRT math scores, as measured by the CRT EOYMT?

Sub-Question 6a. Are scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone, as measured by the CRT EOYMT?

Research Sub-Question 6a was analyzed using independent *t* tests to examine the significance of the difference between students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and students who participated in inquiry-based, hands-on math instruction alone ending 4th-grade compared to ending 4th-grade CRT EOYMT scores. Because multiple statistical tests were conducted, a one-tailed .01 alpha level was employed to help control for Type 1 errors. Means and standard deviations were displayed on tables.

Overarching Posttest-Posttest Criterion-Referenced Test Math Achievement Research Question #7. Do students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction have observed CRT math score improvement frequencies that are the same as for those students who participated in inquiry-based, hands-on math instruction alone, as measured by the CRT EOYMT?

Sub-Question 7a. Are lose, maintain, or improve observed frequencies for the CRT EOYMT scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone, as measured by the CRT EOYMT?

Research Sub-Question #7a utilized a chi-square test of significance to compare observed verses expected end of 4th-grade CRT lose, maintain, or improve score frequencies for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone. Frequencies and percents were displayed in tables.

The following pretest-posttest research questions were used to analyze student participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone measuring behavior outcomes.

Overarching Pretest-Posttest Behavior Research Question #8: Do students who participate in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction lose, maintain, or improve their beginning 4th-grade compared to ending

4th-grade behavior outcomes for (a) absences, (b) tardies, and (c) discipline referrals?

Sub-Question 8a. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade absences, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Sub-Question 8b. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade tardies, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Sub-Question 8c. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade discipline referrals, after completing the inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction school experience?

Research Sub-Questions #8a, 8b, and 8c were analyzed using dependent *t* tests to examine the significance of the difference between inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction students' beginning 4th-grade compared to ending 4th-grade behavior outcomes. Because multiple statistical tests were conducted, a one-tailed .01 alpha level was employed to help control for Type 1 errors. Means and standard deviations were displayed on tables.

Overarching Pretest-Posttest Behavior Research Question #9: Do students who participate in inquiry-based, hands-on math instruction alone lose, maintain, or improve their beginning 4th-grade compared to ending 4th-grade behavior outcomes for (a) absences, (b) tardies, and (c) discipline referrals?

Sub-Question 9a. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade absences, after completing the inquiry-based, hands-on math instruction alone school experience?

Sub-Question 9b. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade tardies, after completing the inquiry-based, hands-on math instruction alone school experience?

Sub-Question 9c. Is there a significant difference between students' beginning 4th-grade compared to ending 4th-grade discipline referrals, after completing the inquiry-based, hands-on math instruction alone school experience?

Research Sub-Questions #9a, 9b, and 9c were analyzed using dependent *t* tests to examine the significance of the difference between inquiry-based, hands-on math instruction alone students' beginning 4th-grade compared to ending 4th-grade behavior outcomes. Because multiple statistical tests were conducted, a one-tailed .01 alpha level was employed to help control for Type 1 errors. Means and standard deviations were displayed on tables.

The following posttest-posttest research questions were used to analyze student participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone measuring behavior outcomes.

Overarching Posttest-Posttest Behavior Research Question #10: Do students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to students who participated in inquiry-based, hands-on math instruction alone have congruent or different end of school year behavior outcome data for (a) absences, (b) tardies, and (c) discipline referrals?

Sub-Question 10a. Are behavior outcome scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone, as measured by the number of students' absences?

Sub-Question 10b. Are behavior outcome scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone, as measured by the number of students' tardies?

Sub-Question 10c. Are behavior outcome scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone, as measured by the number of students' discipline referrals?

Research Sub-Questions #10a, 10b, and 10c were analyzed using independent *t* tests to examine the significance of the difference between students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and students who participated in inquiry-based, hands-on math instruction alone ending 4th-grade number of absences, tardies, and behavioral referrals.

Because multiple statistical tests were conducted, a one-tailed .01 alpha level was employed to help control for Type 1 errors. Means and standard deviations were displayed on tables.

The following posttest-posttest research questions were used to analyze student participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to inquiry-based, hands-on math instruction alone measuring perceptions of math ability.

Overarching Posttest-Posttest Student Perceptions of Math Ability Research Question #11: Do students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to students who participated in inquiry-based, hands-on math instruction alone have congruent or different end of school year perceptions of math ability, as measured by the *Perception of Ability Scale for Students* (PASS)?

Sub-Question 11a. Are the end of the school year perceptions of math ability scores the same for students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction and inquiry-based, hands-on math instruction alone, as measured by the PASS?

Research Question #11a was analyzed using independent *t* tests to examine the significance of the difference between students who participated in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to students who participated in inquiry-based, hands-on math instruction alone ending 4th-grade perception of math ability scores. Because multiple statistical tests were conducted, a one-tailed .01 alpha level was employed to help control for Type 1 errors. Means and standard deviations were displayed on tables.

Data Collection Procedures

All achievement, behavior, and perception data was collected retrospectively, as recorded in SASI. ITBS and EOYMT data is input into SASI each May. The data was accessed and downloaded into a spreadsheet. Behavior data is updated on a continual basis, and this information was also accessed and downloaded into a spreadsheet. The behavior data included students' absences, tardies, and discipline referrals. Students' perceptions of their math ability were gathered in May of 2007 using the PASS. All 4th–grade students participating in the study completed the

PASS. Each of the four participating classrooms completed the PASS under the direction of the Elementary School Curriculum Director. The PASS can be administered to a whole group and was administered in this manner. The primary researcher scored each scale, tabulated the results, and input the data into the spreadsheet that was created for the achievement and behavior data. As a result, the spreadsheet included all achievement, behavior, and perception data. The data from the spreadsheet was copied and pasted into software so that the appropriate statistical tests could be run.

Performance Sites. The research was conducted in two public, elementary school settings through normal educational practices. The study procedures did not interfere in anyway with the normal educational practices of the schools and did not involve coercion or discomfort of any kind.

All data was analyzed in the office of the primary investigator at Washington Elementary School, 207 Scott Street, Council Bluffs, Iowa 51501. This data was stored on spreadsheets and computer memory sticks for statistical analysis. All data and the computer memory stick that the information is saved on were kept in the researcher's locked office file cabinet. Backup data was also stored on the researcher's office computer that is accessible only through a secured password.

Confidentiality. Non-coded numbers were used to display individual, de-identified achievement, behavioral, and perception data. The study data was not anonymized or de-identified until all student information was linked and data sets were complete. The appropriate district personnel anonymized and de-identified all the data sets so that no individual students could be identified. Aggregated group data, descriptive statistics, and parametric statistical analyses were utilized and reported as means and standard deviations using tables. Frequencies and percents were also displayed in tables.

Informed Consent. All student achievement data was retrospective, archival, and routinely collected school information that can be accessed through SASI. In addition, permission to conduct the research project was obtained from the appropriate school officials. Next, perception data was retrospective and was gathered through a published, reliable, and valid scale, the PASS.

Finally, one independent arm included naturally formed groups and the other was randomly selected, for a total of 38 students. Achievement, behavior, and perception data was collected for each of these students. All data was coded so that no individual students are identifiable, regardless of achievement, behavior, or perception. Again, aggregated group data, descriptive statistics, and parametric statistical analyses were utilized and reported as means and standard deviations in tables.

CHAPTER FOUR

Results

Purpose of the Study

The purpose of this study was to determine the math achievement, behavior, and perceived math ability outcomes of 4th-grade students following participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to the math achievement, behavior, and perceived math ability outcomes of 4th-grade students receiving inquiry-based, hands-on math instruction alone.

The study analyzed beginning of the school year pretest compared to ending of the school year posttest data to determine improvement in student outcomes over time and posttest compared to posttest math achievement, behavior, and perceived math ability outcomes data following 4th-grade students' completion of inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to the math achievement, behavior, and perceived math ability outcomes of 4th-grade students receiving inquiry-based, hands-on math instruction alone, to determine independent variable effectiveness.

All study achievement data related to each of the dependent variables were retrospective, archival, and routinely collected school information. Permission from the appropriate school research personnel was obtained before data were collected and analyzed.

Table 1 displays gender and descriptive information of individual 4th-grade students who received inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction. Table 2 displays gender and descriptive information of individual 4th-grade students who received inquiry-based hands-on math instruction alone. Iowa Test of Basic Skills Math Subtest Normal Curve Equivalent Scores for 4th-grade students who received inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction are found in Table 3. Iowa Test of Basic Skills Math Subtest Normal Curve Equivalent Scores for 4th-grade students who received inquiry-based hands-on math instruction alone may be found in Table 4. Table 5 displays 4th-grade students who received inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction pretest compared to posttest Iowa Test of Basic Skills Normal Curve Equivalent Scores.

Research Question #1

The first hypothesis comparing students' who received inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction dependent *t* test pretest-posttest Iowa Test of Basic Skills Normal Curve Equivalent scores for Problem Solving/Data Analysis, Concepts/Estimation, Math Total, and Math Computation results were displayed in Table 5. As seen in Table 5 the null hypothesis was not rejected for any of the four measured math achievement subtests. The pretest Problem Solving/Data Analysis score (M = 46.32, SD = 15.83) compared to the posttest Problem Solving/Data Analysis score (M = 47.79, SD = 18.90) was not statistically significantly different, $t(18) = 0.36$, $p = 0.36$ (one-tailed), $d = .08$. The pretest Concepts/Estimation score (M = 43.89, SD = 18.29) compared to the posttest Concepts/Estimation score (M = 43.79, SD = 19.30) was not statistically significantly different, $t(18) = -0.04$, p = 0.48 (one-tailed), $d = .00$. The pretest Math Total score (M = 44.47, SD = 16.61) compared to the posttest Math Total score (M = 45.53, SD = 18.54) was not statistically significantly different, $t(18) = 0.32$, $p = 0.38$ (one-tailed), $d = .06$. The pretest Math Computation score (M = 41.79, SD = 16.64) compared to the posttest Math

Computation score (M = 43.11, SD = 16.47) was not statistically significantly different, $t(18) = 0.43$, p = 0.34 (one-tailed), d = .08.

Overall, pretest-posttest results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction did not significantly improve their Problem Solving/Data Analysis, Concepts/Estimation, Math Total, and Math Computation achievement test score results. Comparing students' NRT NCE scores in math with derived achievement scores puts their performance in perspective. An NRT NCE posttest Problem Solving/Data Analysis mean score of 47.79 is congruent with a Standard Score of 99, a Percentile Rank of 47, a Stanine Score of 5, and an achievement qualitative description of Average. An NRT NCE posttest Concepts/Estimation mean score of 43.79 is congruent with a Standard Score of 96, a Percentile Rank of 39, a Stanine Score of 4, and an achievement qualitative description of Average. An NRT NCE posttest Math Total mean score of 45.53 is congruent with a Standard Score of 97, a Percentile Rank of 42, a Stanine Score of 5, and an achievement qualitative description of Average. Finally, an NRT NCE posttest Math Computation mean score of 43.11 is congruent with a Standard Score of 96, a

Percentile Rank of 39, a Stanine Score of 4, and an achievement qualitative description of Average.

Research Question #2

The second hypothesis comparing students' who received inquiry-based hands-on math instruction alone dependent *t* test pretest-posttest Iowa Test of Basic Skills Normal Curve Equivalent scores for Problem Solving/Data Analysis, Concepts/Estimation, Math Total, and Math Computation results were displayed in Table 6. As seen in Table 6 the predetermined .01 alpha level set for rejecting the null hypothesis was not obtained for any of the four measured math achievement subtests. However, the Concepts/Estimation pretest-posttest comparison was statistically significantly different; *p* value was less than .05, as indicated in Table 6. The pretest Problem Solving/Data Analysis score (M = 54.36, SD = 21.55) compared to the posttest Problem Solving/Data Analysis score (M = 56.89, SD = 14.06) was not statistically significantly different, $t(18) = 0.53$, p = 0.30 (one-tailed), d = .14. The pretest Concepts/Estimation score (M = 48.63, SD = 18.79) compared to the posttest Concepts/Estimation score (M = 56.16, SD = 16.68) was statistically significantly different, $t(18) = 1.81$, p = 0.04 (one-tailed), d = .42. The pretest Math Total score (M = 51.37, SD = 21.09) compared to the posttest Math Total score (M = 56.26, SD = 14.77) was not statistically significantly different, $t(18) = 1.13$, $p = 0.14$ (one-tailed), $d = .27$. The pretest Math Computation score (M = 46.68, SD = 21.05) compared to the posttest Math Computation score (M = 53.79, SD = 18.85) was not statistically significantly different, $t(18) = 1.38$, $p =$ 0.09 (one-tailed), $d = .35$.

Overall, pretest-posttest results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction used alone did not significantly improve their Problem Solving/Data Analysis, Math Total, and Math Computation achievement test score results but did significantly improve their Concepts/Estimation achievement test score results. Comparing students' NRT NCE scores in math with derived achievement scores puts their performance in perspective. An NRT NCE posttest Problem Solving/Data Analysis mean score of 56.89 is congruent with a Standard Score of 105, a Percentile Rank of 63, a Stanine Score of 6, and an achievement qualitative description of Average. An NRT NCE posttest Concepts/Estimation mean score of 56.16 is congruent with a Standard Score of 105, a Percentile Rank of 63, a Stanine Score of 6, and an achievement qualitative description of Average. An NRT NCE posttest Math Total mean score of 56.26 is congruent with a Standard

Score of 105, a Percentile Rank of 63, a Stanine Score of 6, and an achievement qualitative description of Average. Finally, an NRT NCE posttest Math Computation mean score of 53.79 is congruent with a Standard Score of 102, a Percentile Rank of 55, a Stanine Score of 5, and an achievement qualitative description of Average.

Research Question #3

The third hypothesis was tested using the independent *t* test. A comparison of 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction and 4th-grade students who received inquiry-based hands-on math instruction alone posttest compared to posttest Iowa Test of Basic Skills Normal Curve Equivalent results were displayed in Table 7. As seen in Table 7 the predetermined .01 alpha level set for rejecting the null hypothesis was not obtained for any of the four measured math achievement subtests. However, posttest-posttest comparison *p* values less than .05 were obtained for all four, math subtests as indicated in Table 7. The posttest Problem Solving/Data Analysis score for the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group (M = 47.79, SD = 18.90) compared to the posttest Problem Solving/Data

Analysis score for the inquiry-based hands-on math instruction alone group (*M* = 56.89, *SD* = 14.06) was statistically significantly different, $t(36) = 1.68$, $p = 0.05$ (one-tailed), $d = .55$. The posttest Concepts/Estimation score for the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group (*M* = 43.79, *SD* = 19.30) compared to the posttest Concepts/Estimation score for the inquiry-based hands-on math instruction alone group (*M* = 56.16, *SD* = 16.68) was statistically significantly different, $t(36) = 2.11$, $p = 0.02$ (one-tailed), $d = .68$. The posttest Math Total score for the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group (*M* = 45.53, *SD* = 18.54) compared to the posttest Math Total score for the inquiry-based hands-on math instruction alone group (*M* = 56.26, *SD* = 14.77) was statistically significantly different, $t(36) = 1.97$, $p = 0.03$ (one-tailed), $d = .64$. The posttest Math Computation score for the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group (*M* = 43.11, *SD* = 16.47) compared to the posttest Math Computation score for the inquiry-based hands-on math instruction alone group

(M = 53.79, SD = 18.85) was statistically significantly different, $t(36) = 1.86$, $p = 0.04$ (one-tailed), $d = .60$.

Overall, results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction used alone group did significantly improve their posttest Problem Solving/Data Analysis, Concepts/Estimation, Math Total, and Math Computation achievement test score results compared to the posttest Problem Solving/Data Analysis, Concepts/Estimation, Math Total, and Math Computation achievement test score results for the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group. Given the consistency of the statistical results for all four subtests and the moderate effect sizes observed across all four posttest-posttest comparisons using the .05 level of significance for rejecting the null hypotheses insures a lower chance of making a type II error. This error consists of *not* rejecting the null hypothesis when the data supports that it should be rejected.

Research Question #4

Table 8 displays school district administered criterion-referenced math test scores for 4th-grade students who received inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction and 4th-grade students who received inquiry-based hands-on math instruction alone.

The fourth hypothesis comparing students who received inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction dependent *t* test pretest compared to posttest district administered criterion-referenced math test results were displayed in Table 9. As seen in Table 9 the null hypothesis was not rejected. The pretest District Administered Criterion-Referenced Math Test score (M = 21.53, SD = 5.51) compared to the posttest District Administered Criterion-Referenced Math Test score (M = 20.05, SD = 5.89) was not statistically significantly different, $t(18) = -1.38$, p = 0.09 (one-tailed), d = .26.

Overall, pretest-posttest results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction did not significantly improve their District Administered Criterion-Referenced Math Test score results. Comparing students' District Administered Criterion-Referenced Math Test score results with district level derived achievement cut scores puts their performance in perspective. Criterion-referenced Math test scores range from zero to 35 with a mid-point of 17.5. Pretest-posttest results for 4th-grade students who received inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction indicate mean scores (21.53, 20.05) above the mid-point. Scores 14 or below represent the 10th percentile and lower based on school district analysis and result in individual student referral for assessment and special services eligibility.

Research Question #5

The fifth hypothesis comparing students who received inquiry-based hands-on math instruction alone dependent *t* test pretest compared to posttest district administered criterion-referenced math test results were displayed in Table 10. As seen in Table 10 the null hypothesis was not rejected. The pretest District Administered Criterion-Referenced Math Test score (M = 22.68, SD = 5.24) compared to the posttest District Administered Criterion-Referenced Math Test score (M = 23.42, SD = 4.35) was not statistically significantly different, $t(18) = 0.72$, p = 0.24 (one-tailed), d = .15.

Overall, pretest-posttest results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction alone did not significantly improve their

District Administered Criterion-Referenced Math Test score results. Comparing students' District Administered Criterion-Referenced Math Test score results with district level derived achievement cut scores puts their performance in perspective. Criterion-referenced Math test scores range from zero to 35 with a mid-point of 17.5. Pretest-posttest results for 4th-grade students who received inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction indicate mean scores (22.68, 23.42) above the mid-point. Scores 14 or below represent the 10th percentile and lower based on school district analysis and result in individual student referral for assessment and special services eligibility.

Research Question #6

The sixth hypothesis was tested using the independent *t* test. A comparison of 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction and 4th-grade students who received inquiry-based hands-on math instruction alone posttest compared to posttest district administered criterion-referenced math test scores. As seen in Table 11 the predetermined .01 alpha level set for rejecting the null hypothesis was not obtained for the posttest-posttest comparison of the district administered criterion-referenced math test scores. The posttest district administered criterion-referenced math test score for the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group (*M* = 20.05, *SD* = 5.89) compared to the posttest district administered criterion-referenced math test score for the inquiry-based hands-on math instruction alone group (*M* = 22.68, *SD* = 5.24) was not statistically significantly different, $t(36) = 1.45$, $p = 0.08$ (one-tailed), $d = .47$.

Overall, results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction used alone group had a higher but not statistically significantly different posttest mean district administered criterion-referenced math test score.

Research Question #7

A comparison of 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction and 4th-grade students who received inquiry-based hands-on math instruction alone posttest compared to posttest district administered criterion-referenced math test improvement frequency scores are found in Table 12. The seventh hypothesis was tested using chi-square (X^2). The result of X^2 displayed in Table 12 was not statistically significantly different ($X^2(1, N = 38) = .94, p = < .40$) so we do not reject the null hypothesis of no difference or congruence for students' posttest compared to posttest district administered criterion-referenced math test improvement frequency scores.

Inspecting our frequency and percent findings in Table 12 we find that 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction had lower scores on posttest (9, 47%) and improved scores on posttest (10, 53%) that were not significantly different from the reported lower scores on posttest (12, 63%) and improved scores on posttest (7, 37%) for 4th-grade students participating in the inquiry-based hands-on math instruction alone group. While some frequency and corresponding percent variance is noted in Table 12 the lower scores and improved scores comparisons represent near numerical equipoise.

Research Question #8

Table 13 displays pretest-posttest absences, tardies, and discipline referrals for 4th-grade students who received inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction and Table 14 displays the pretest-posttest absences, tardies, and discipline referrals for 4th-grade students who received inquiry-based hands-on math instruction alone.

The eighth hypothesis comparing students who received inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction dependent *t* test pretest compared to posttest absence, tardies, and discipline referrals were displayed in Table 15. As seen in Table 15 the null hypothesis was not rejected for any of the three pretest-posttest statistical comparisons. The pretest absence score (M = 7.68, SD = 6.36) compared to the posttest absence score (M = 6.79, SD = 5.02) was not statistically significantly different, $t(18) = -0.87$, p = 0.20 (one-tailed), d = .16. The pretest tardies score (M = 10.68, SD = 13.25) compared to the posttest tardies score (M = 8.37, SD = 9.59) was not statistically significantly different, $t(18) = -1.00$, p = 0.17 (one-tailed), d = .20. The pretest discipline referrals score (M = 0.58, SD = 1.12) compared to the posttest discipline referrals score (M = 0.63, SD = 1.21) was not statistically significantly different, $t(18) = 0.18$, p = 0.43 (one-tailed), d = .04.

Overall, pretest-posttest results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction did not significantly improve their absences, tardies, and discipline referrals score results. However, negative posttest absences and tardies *t* test results were in the direction of student improvement in these two behavioral measures with fewer ending of school year absences and tardies. Students' posttest, mean absences scores (6.79) were lower than the school district threshold (10) requiring administrative intervention. Students' posttest, mean tardies scores (8.37) were lower than the school district threshold (15) requiring administrative intervention. Students' posttest, mean discipline referrals scores (0.63) indicate almost no student discipline issues for 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group.

Research Question #9

The ninth hypothesis comparing students who received inquiry-based hands-on math instruction alone dependent *t* test pretest compared to posttest absence, tardies, and discipline referrals were displayed in Table 16. As seen in Table 16 the null hypothesis was not rejected for any of the three pretest-posttest statistical comparisons. The pretest absence score (*M* = 5.84, *SD* = 5.09) compared to the posttest absence score (*M* = 7.37, *SD* = 6.04) was not statistically significantly different, $t(18) = 1.55$, $p = 0.07$ (one-tailed), $d = .26$. The pretest tardies score (*M* = 5.32, *SD* = 10.81) compared to the posttest tardies score (*M* = 4.58, *SD* = 7.97) was not statistically significantly different, $t(18) = -0.59$, $p = 0.28$ (one-tailed), $d = .08$. The pretest discipline referrals score (*M* = 0.32, *SD* = 1.16) compared to the posttest discipline referrals score (*M* = 0.16, *SD* = 0.50) was not statistically significantly different, $t(18) = -0.90$, $p = 0.19$ (one-tailed), $d = .19$.

Overall, pretest-posttest results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction alone did not significantly improve their absences, tardies, and discipline referrals score results. However, negative posttest tardies and discipline referrals *t* test results were in the direction of student improvement in these two behavioral measures with fewer ending of school year tardies and discipline referrals. Students' posttest, mean absences scores (7.37) were lower than the school district threshold (10) requiring administrative intervention. Students' posttest, mean tardies scores (4.58) were lower than the school district threshold (15) requiring administrative intervention. Students' posttest, mean discipline referrals scores (0.16) indicate almost no student discipline issues for 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group.

Research Question #10

The tenth hypothesis was tested using the independent *t* test. A comparison of 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction and 4th-grade students who received inquiry-based hands-on math instruction alone posttest compared to posttest absences, tardies, and discipline referrals scores are found in Table 17. As seen in Table 17 the predetermined .01 alpha level set for rejecting the null hypothesis was not obtained for the posttest-posttest comparison of the absences, tardies, and discipline referrals scores. The posttest absences score for the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group (M = 6.79, SD = 5.02) compared to the posttest absences score for the inquiry-based hands-on math instruction alone group (M = 7.37, SD = 6.04) was not statistically significantly different, $t(36) = 0.32$, $p = 0.37$ (one-tailed), d = .10.

The posttest tardies score for the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group (*M* = 8.37, *SD* = 9.59) compared to the posttest tardies score for the inquiry-based hands-on math instruction alone group (*M* = 4.58, *SD* = 7.97) was not statistically significantly different, $t(36) = -1.32$, $p = 0.10$ (one-tailed), $d = .43$. The posttest discipline referrals score for the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group (*M* = 0.63, *SD* = 1.21) compared to the posttest discipline referrals score for the inquiry-based hands-on math instruction alone group (*M* = 0.16, *SD* = 0.50) was not statistically significantly different, $t(36) = -1.57$, $p = 0.06$ (one-tailed), $d = .55$.

Overall, results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction alone group compared to 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted group had a higher but not statistically significantly different mean posttest absences score. Further results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction alone group compared to 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted group had a lower but not statistically significantly different mean posttest tardies score. Finally, results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction alone group compared to 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted group had a lower but not statistically significantly different mean posttest discipline referrals score.

Research Question #11

Table 18 displays the Perceptions of Ability Scale for Students (PASS) Posttest Math Percentile Rank Scores for 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction and 4th-grade students who received inquiry-based hands-on math instruction alone.

The eleventh hypothesis was tested using the independent *t* test. A comparison of 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction and 4th-grade students who received inquiry-based hands-on math instruction alone posttest compared to posttest math Perceptions of Ability Scale for Students scores are found in Table 19. As seen in Table 19 the predetermined .01 alpha level set for rejecting the null hypothesis was not obtained for the posttest-posttest comparison of the math Perceptions of Ability Scale for Students scores. The posttest math Perceptions of Ability Scale for Students score for the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group (*M* = 40.11, *SD* = 31.38) compared to the posttest math Perceptions of Ability Scale for Students score for the inquiry-based hands-on math instruction alone group (*M* = 50.58, *SD* = 28.89) was not statistically significantly different, $t(36) = 1.07$, $p = 0.15$ (one-tailed), $d = .35$.

Overall, results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction alone group mean posttest math Perceptions of Ability Scale for Students percentile rank score (50th-percentile) was at the test median 50th-percentile rank. Results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group mean posttest math Perceptions of Ability Scale for Students percentile rank score (40th-percentile) was below the test median 50th-percentile rank. Scores ranging from the 40th-percentile to the 60th-percentile indicate that the child likes math and believes that she/he is not experiencing difficulty in performing basic math functions and completing math assignments at school (Boersma & Chapman, 1992).

Table 1

Gender and Descriptive Information of Individual 4th-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Used in Combination with Web-Based Computer-Assisted Math Instruction

Student Number	Gender	Free and Reduced Price Lunch Status	Special Education Accommodations
1.	Female	Yes	No
2.	Female	No	No
3.	Female	Yes	No
4.	Male	Yes	No
5.	Male	Yes	No
6.	Male	Yes	No
7.	Male	Yes	No
8.	Female	No	No
9.	Male	Yes	No
10.	Male	Yes	No
11.	Female	Yes	No
12.	Female	No	No
13.	Female	Yes	No
14.	Female	Yes	No
15.	Male	Yes	No
16.	Female	Yes	No
17.	Male	No	No
18.	Male	Yes	Yes (a)
19.	Male	Yes	Yes (b)

(a) Note: Student on formal intervention plan to prevent special education verification.
(b) Note: Student verified special education participating in regular classroom instruction.

Table 2

Gender and Descriptive Information of Individual 4th-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Alone

Student Number	Gender	Free and Reduced Price Lunch Status	Special Education Accommodations
1.	Male	No	No
2.	Male	Yes	No
3.	Male	No	No
4.	Male	Yes	No
5.	Female	No	No
6.	Female	No	No
7.	Male	No	No
8.	Male	Yes	No
9.	Male	No	No
10.	Male	No	No
11.	Male	No	No
12.	Male	Yes	No
13.	Male	No	No
14.	Female	Yes	No
15.	Male	No	Yes (a)
16.	Male	Yes	Yes (a)
17.	Male	Yes	Yes (b)
18.	Male	Yes	Yes (b)
19.	Female	No	Yes (b)

(a) Note: Student on formal intervention plan to prevent special education verification.

(b) Note: Student verified special education participating in regular classroom instruction.

Table 3

Iowa Test of Basic Skills Math Subtest Normal Curve Equivalent Scores for 4th-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Used in Combination with Web-Based Computer-Assisted Math Instruction

(a)	Problem Solving/ Data Analysis		Concepts/ Estimation		Math Total		Math Computation	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1.	24	40	25	31	22	34	13	32
2.	39	33	25	15	31	25	27	15
3.	43	69	36	57	39	64	45	59
4.	68	64	51	57	62	61	68	59
5.	68	76	69	78	59	78	57	71
6.	59	64	57	61	62	62	48	54
7.	15	40	39	31	25	34	25	34
8.	43	25	36	50	39	38	39	27
9.	43	64	47	57	46	61	57	59
10.	66	64	66	68	67	67	48	62
11.	20	45	6	15	10	31	1	20
12.	59	64	60	54	60	60	57	47
13.	46	50	45	38	46	43	45	54
14.	50	15	25	20	38	13	57	24
15.	53	57	60	45	55	51	36	43
16.	55	60	55	64	54	61	51	48
17.	26	25	15	15	20	20	41	43
18.	53	38	51	31	53	33	31	20
19.	50	15	66	45	57	29	48	48

(a) Note: Student numbers correspond with Table 1.

Table 4

Iowa Test of Basic Skills Math Subtest Normal Curve Equivalent Scores for 4th-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Alone

(a)	Problem Solving/ Data Analysis Pre	Post	Concepts/ Estimation Pre	Post	Math Total Pre	Post	Math Computation Pre	Post
1.	55	76	55	95	54	87	31	62
2.	39	57	47	54	43	54	41	51
3.	96	76	96	64	96	71	89	76
4.	15	47	17	47	10	47	21	47
5.	59	60	55	61	57	60	27	54
6.	62	45	39	54	51	48	45	34
7.	89	69	74	68	83	69	76	66
8.	43	45	47	29	46	36	39	27
9.	73	60	66	50	71	54	76	48
10.	66	50	51	78	60	62	51	96
11.	66	60	51	68	60	62	39	71
12.	50	40	55	54	53	46	45	34
13.	59	53	47	47	54	50	60	39
14.	24	38	21	29	20	33	13	47
15.	24	76	36	50	27	67	45	43
16.	78	64	66	68	74	67	81	87
17.	53	60	36	61	45	60	36	43
18.	43	76	36	61	39	69	27	62
19.	39	29	29	29	33	27	45	35

(a) Note: Student numbers correspond with Table 2.

Table 5

Fourth-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Used in Combination with Web-Based Computer-Assisted Math Instruction Pretest Compared to Posttest Iowa Test of Basic Skills Normal Curve Equivalent Scores

	Pretest Scores		Posttest Scores				
Source Of Data	Mean	*SD*	Mean	*SD*	Effect Size	*t*	*p*
Problem Solving/ Data Analysis	46.32	(15.83)	47.79	(18.90)	0.08	0.36	.36*
Concepts/ Estimation	43.89	(18.29)	43.79	(19.30)	0.00	-0.04	.48*
Math Total	44.47	(16.61)	45.53	(18.54)	0.06	0.32	.38*
Math Computation	41.79	(16.64)	43.11	(16.47)	0.08	0.43	.34*

**ns*.

Table 6

Fourth-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Alone Pretest Compared to Posttest Iowa Test of Basic Skills Normal Curve Equivalent Scores

	Pretest Scores		Posttest Scores				
Source Of Data	Mean	*SD*	Mean	*SD*	Effect Size	*t*	*p*
Problem Solving/ Data Analysis	54.36	(21.55)	56.89	(14.06)	0.14	0.53	.30*
Concepts/ Estimation	48.63	(18.79)	56.16	(16.68)	0.42	1.81	.04**
Math Total	51.37	(21.09)	56.26	(14.77)	0.27	1.13	.14*
Math Computation	46.68	(21.05)	53.79	(18.85)	0.35	1.38	.09*

**ns.* ** *p* = .04.

Table 7

Fourth-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Used in Combination with Web-Based Computer-Assisted Math Instruction and 4th-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Alone Posttest Compared to Posttest Iowa Test of Basic Skills Normal Curve Equivalent Scores

	Web-Based Combination Math Instruction Posttest Scores		Inquiry-Based Hands-On Math Instruction Alone Posttest Scores				
Source Of Data	Mean	*SD*	Mean	*SD*	Effect Size	*t*	*p*
Problem Solving/ Data Analysis	47.79	(18.90)	56.89	(14.06)	0.55	1.68	.05**
Concepts/ Estima-tion	43.79	(19.30)	56.16	(15.68)	0.68	2.11	.02**
Math Total	45.53	(18.54)	56.26	(14.77)	0.64	1.97	.03**
Math Computa-tion	43.11	(16.47)	53.79	(18.85)	0.60	1.86	.04**

**p = .05, or less, with posttest-posttest comparisons in the direction of greater mean scores observed for students in the Inquiry-Based Hands-On Math Instruction Alone group.

Table 8

School District Administered Criterion-Referenced Math Test Scores for 4th-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Used in Combination with Web-Based Computer-Assisted Math Instruction and 4th-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Alone

	Web-Based Combination Math Instruction (a,c)			Inquiry-Based Hands-On Math Instruction Alone (b,c)		
	Pre	Post	Change	Pre	Post	Change
1.	17	11	–	22	29	+
2.	14	17	+	18	24	+
3.	24	28	+	30	28	–
4.	27	22	–	21	10	–
5.	26	27	+	24	23	–
6.	26	22	–	26	24	–
7.	19	9	–	29	30	+
8.	23	20	–	17	14	–
9.	27	24	–	28	26	–
10.	25	26	+	23	24	+
11.	13	14	+	28	27	–
12.	28	19	–	26	21	–
13.	25	28	+	25	24	–
14.	10	18	+	17	16	–
15.	24	19	–	20	25	+
16.	23	25	+	30	24	–
17.	14	13	–	22	17	–
18.	19	14	–	20	25	+
19.	25	25	0	19	20	+

(a) Note: Student numbers correspond with Table 1.
(b) Note: Student numbers correspond with Table 2.
(c) Note: Scores less than 15 are below the 10th percentile.

Table 9

Fourth-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Used in Combination with Web-Based Computer-Assisted Math Instruction Pretest Compared to Posttest District Administered Criterion-Referenced Math Test Scores

	Pretest Scores		Posttest Scores				
Source Of Data	Mean	*SD*	Mean	*SD*	Effect Size	*t*	*p*
District Administered Criterion-Referenced Math Test	21.53	(5.51)	20.05	(5.89)	0.26	-1.38	.09*

**ns.*

Table 10

Fourth-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Alone Pretest Compared to Posttest District Administered Criterion-Referenced Math Test Scores

	Pretest Scores		Posttest Scores				
Source Of Data	Mean	*SD*	Mean	*SD*	Effect Size	*t*	*p*
District Administered Criterion-Referenced Math Test	23.42	(4.35)	22.68	(5.24)	0.15	-0.72	.24*

**ns*.

Table 11

Fourth-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Used in Combination with Web-Based Computer-Assisted Math Instruction and 4th-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Alone Posttest Compared to Posttest District Administered Criterion-Referenced Math Test Scores

	Hands-On Web-Based Combination Math Instruction Posttest Scores		Hands-On Math Instruction Alone Posttest Scores				
Source Of Data	Mean	*SD*	Mean	*SD*	Effect Size	*t*	*p*
District Administered Criterion-Referenced Math Test	20.05	(5.89)	22.68	(5.24)	0.47	1.45	.08*

**ns*.

Table 12

Observed Posttest-Posttest District Administered Criterion-Referenced Math Test Lower and Improved Scores Frequencies

	A		B		
Group	*N*	%	*N*	%	X^2
Lower Scores	9	(47)	12	(63)	
Improved Scores	10	(53)	7	(37)	
Totals	19	(100)	19	(100)	0.94*

A = 4th-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Used in Combination with Web-Based Computer-Assisted Math Instruction; B = 4th-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Alone

* Note: *ns* for Observed verses Expected cell frequencies with $df = 1$ and a tabled value = 6.63 for $p < .01$.

Table 13

Absences, Tardies, and Discipline Referrals for 4th-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Used in Combination with Web-Based Computer-Assisted Math Instruction

(a)	Absences		Tardies		Discipline Referrals	
	Pre	Post	Pre	Post	Pre	Post
1.	10	8	32	7	0	0
2.	5	4	6	7	0	0
3.	2	8	1	2	0	0
4.	23	14	4	2	0	0
5.	5	8	24	3	0	0
6.	4	10	2	0	0	0
7.	2	4	3	4	0	0
8.	9	8	12	14	0	0
9.	4	1	0	0	0	1
10.	8	6	30	32	1	2
11.	9	9	6	10	0	0
12.	8	7	45	27	0	0
13.	10	3	2	0	0	0
14.	5	1	4	1	1	2
15.	11	1	2	7	1	4
16.	24	22	22	16	0	0
17.	3	7	1	22	4	0
18.	3	5	7	4	3	3
19.	1	3	0	1	1	0

(a) Note: Student numbers correspond with Table 1.

Table 14

Absences, Tardies, and Discipline Referrals for 4th-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Alone

	Absences		Tardies		Discipline Referrals	
(a)	Pre	Post	Pre	Post	Pre	Post
1.	1	2	9	3	0	0
2.	4	2	0	2	0	0
3.	8	5	22	6	0	0
4.	0	14	0	2	0	0
5.	3	2	0	1	0	0
6.	4	5	0	1	0	0
7.	16	15	1	7	0	0
8.	4	5	1	0	5	2
9.	4	3	7	5	0	0
10.	1	1	1	0	0	0
11.	12	13	3	5	0	0
12.	11	9	0	0	0	0
13.	4	2	0	0	0	0
14.	0	3	0	1	0	1
15.	1	6	3	3	0	0
16.	6	15	2	1	0	0
17.	11	14	8	17	1	0
18.	16	21	44	33	0	0
19.	5	3	0	0	0	0

(a) Note: Student numbers correspond with Table 2.

Table 15

Fourth-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Used in Combination with Web-Based Computer-Assisted Math Instruction Pretest Compared to Posttest Absences, Tardies, and Discipline Referral Data

	Pretest Scores		Posttest Scores				
Source Of Data	Mean	*SD*	Mean	*SD*	Effect Size	*t* (a)	*p*
Absences	7.68	(6.36)	6.79	(5.02)	0.16	-0.87	.20*
Tardies	10.68	(13.25)	8.37	(9.59)	0.20	-1.00	.17*
Discipline Referrals	0.58	(1.12)	0.63	(1.21)	0.04	0.18	.43*

(a) Note: Negative *t* scores for absences and tardies are in the direction of improvement.

**ns*.

Table 16

Fourth-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Alone Pretest Compared to Posttest Absences, Tardies, and Discipline Referral Data

	Pretest Scores		Posttest Scores				
Source Of Data	Mean	*SD*	Mean	*SD*	Effect Size	*t* (a)	*p*
Absences	5.84	(5.09)	7.37	(6.04)	0.26	1.55	.07*
Tardies	5.32	(10.81)	4.58	(7.97)	0.08	-0.59	.28*
Discipline Referrals	0.32	(1.16)	0.16	(0.50)	0.19	-0.90	.19*

(a) Note: Negative *t* scores for tardies and discipline referrals are in the direction of improvement.

**ns*.

Table 17

Fourth-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Used in Combination with Web-Based Computer-Assisted Math Instruction and 4th-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Alone Posttest Compared to Posttest Absences, Tardies, and Discipline Referral Data

	Web-Based Combination Math Instruction Posttest Scores		Inquiry-Based Hands-On Math Instruction Alone Posttest Scores				
Source Of Data	Mean	*SD*	Mean	*SD*	Effect Size	*t*	*p*
Absences	6.79	(5.02)	7.37	(6.04)	0.10	0.32	.37*
Tardies	8.37	(9.59)	4.58	(7.97)	0.43	-1.32	.10*
Discipline Referrals	0.63	(1.21)	0.16	(0.50)	0.55	-1.57	.06*

**ns*.

Table 18

Perceptions of Ability Scale for Students (PASS) Posttest Math Percentile Rank Scores

	Web-Based Combination Math Instruction (a)	Inquiry-Based Hands-On Math Instruction Alone (b)
	Posttest Percentile	Posttest Percentile
1.	7	21
2.	10	58
3.	50	99
4.	62	50
5.	99	50
6.	73	44
7.	31	31
8.	7	42
9.	99	99
10.	42	99
11.	69	27
12.	38	99
13.	27	31
14.	27	18
15.	8	73
16.	1	31
17.	31	31
18.	8	31
19.	73	27

(a) Note: Student numbers correspond with Table 1.
(b) Note: Student numbers correspond with Table 2.

Table 19

Fourth-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Used in Combination with Web-Based Computer-Assisted Math Instruction and 4th-Grade Students Who Received Inquiry-Based Hands-On Math Instruction Alone Posttest Compared to Posttest Perceptions of Ability Scale for Students (PASS) Percentile Rank Scores

	Web-Based Combination Math Instruction Posttest Scores		Inquiry-Based Hands-On Math Instruction Alone Posttest Scores				
Source Of Data	Mean	*SD*	Mean	*SD*	Effect Size	*t*	*p*
Math Perceptions							
	40.11	(31.38)	50.58	(28.89)	0.35	1.07	.15*

**ns.*

CHAPTER FIVE

Conclusions and Discussion

Purpose of study. The purpose of this study was to determine the math achievement, behavior, and perceived math ability outcomes of 4th-grade students following participation in inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to the math achievement, behavior, and perceived math ability outcomes of 4th-grade students receiving inquiry-based, hands-on math instruction alone.

The study analyzed beginning of the school year pretest compared to ending of the school year posttest data, to determine improvement in student outcomes over time and posttest compared to posttest math achievement, behavior, and perceived math ability outcomes data following 4th-grade students' completion of inquiry-based, hands-on math instruction utilized in combination with web-based, computer-assisted math instruction compared to the math achievement, behavior, and perceived math ability outcomes of 4th-grade students receiving inquiry-based, hands-on math instruction alone to determine independent variable effectiveness. All study achievement data related to each of these dependent variables were retrospective, archival, and routinely collected school information. Permission from the appropriate school research personnel was obtained before data were collected and analyzed.

Fourth-grade (1) Achievement was determined by beginning and ending of the school year (a) ITBS NCE, (*i*) Math Problem Solving/Data Analysis, (ii) Math Concepts/Estimation, (*iii*) Math Total, and (iv) Math Computation, and (b) District Criterion-Referenced Test. Fourth-grade (2) Behavior was determined by beginning and ending of the school year (a) absence data, (b) tardy data, and (c) discipline referral data. Perceptions of math abilities, (3) was determined by ending of the school year Perceived Math Ability Scale scores.

Conclusions

Research Question #1

Overall, pretest-posttest results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction did not significantly improve their Problem Solving/Data Analysis, Concepts/Estimation, Math Total, and Math Computation achievement test score results. Comparing students' NRT NCE scores in math with derived achievement scores puts their performance in perspective. An NRT NCE posttest Problem

Solving/Data Analysis mean score of 47.79 is congruent with a Standard Score of 99, a Percentile Rank of 47, a Stanine Score of 5, and an achievement qualitative description of Average. An NRT NCE posttest Concepts/Estimation mean score of 43.79 is congruent with a Standard Score of 96, a Percentile Rank of 39, a Stanine Score of 4, and an achievement qualitative description of Average. An NRT NCE posttest Math Total mean score of 45.53 is congruent with a Standard Score of 97, a Percentile Rank of 42, a Stanine Score of 5, and an achievement qualitative description of Average. Finally, an NRT NCE posttest Math Computation mean score of 43.11 is congruent with a Standard Score of 96, a Percentile Rank of 39, a Stanine Score of 4, and an achievement qualitative description of Average. Three of the four ITBS NCE posttest scores were in the direction of pretest-posttest improvement Problem Solving/Data Analysis, Math Total, and Math Computation. The Concepts/Estimation ITBS NCE posttest score was in the direction of pretest-posttest decline but only by .10.

Research Question #2

Overall, pretest-posttest results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction used alone did not significantly improve their Problem Solving/Data Analysis, Math Total, and Math

Computation achievement test score results but did significantly improve their Concepts/Estimation achievement test score results. Comparing students' NRT NCE scores in math with derived achievement scores puts their performance in perspective. An NRT NCE posttest Problem Solving/Data Analysis mean score of 56.89 is congruent with a Standard Score of 105, a Percentile Rank of 63, a Stanine Score of 6, and an achievement qualitative description of Average. An NRT NCE posttest Concepts/Estimation mean score of 56.16 is congruent with a Standard Score of 105, a Percentile Rank of 63, a Stanine Score of 6, and an achievement qualitative description of Average. An NRT NCE posttest Math Total mean score of 56.26 is congruent with a Standard Score of 105, a Percentile Rank of 63, a Stanine Score of 6, and an achievement qualitative description of Average. Finally, an NRT NCE posttest Math Computation mean score of 53.79 is congruent with a Standard Score of 102, a Percentile Rank of 55, a Stanine Score of 5, and an achievement qualitative description of Average. All four of the ITBS NCE posttest scores were in the direction of pretest-posttest improvement Problem Solving/Data Analysis, Concepts/Estimation, Math Total, and Math Computation.

Research Question #3

Overall, results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction used alone group did significantly improve their posttest Problem Solving/Data Analysis, Concepts/Estimation, Math Total, and Math Computation achievement test score results compared to the posttest Problem Solving/Data Analysis, Concepts/Estimation, Math Total, and Math Computation achievement test score results for the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group. Given the consistency of the statistical results for all four subtests and the moderate effect sizes observed across all four posttest-posttest comparisons using the .05 level of significance for rejecting the null hypotheses insures a lower chance of making a type II error. This error consists of *not* rejecting the null hypothesis when the data supports that it should be rejected.

Research Question #4

Overall, pretest-posttest results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction did not significantly improve their District Administered Criterion-Referenced

Math Test score results. Comparing students' District Administered Criterion-Referenced Math Test score results with district level derived achievement cut scores puts their performance in perspective. Criterion-referenced Math test scores range from zero to 35 with a mid-point of 17.5. Pretest-posttest results for 4th-grade students who received inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction indicate mean scores (21.53, 20.05) above the mid-point. Scores 14 or below represent the 10th percentile and lower based on school district analysis and result in individual student referral for assessment and special services eligibility. The District Administered Criterion-Referenced Math Test posttest score was in the direction of pretest-posttest decline.

Research Question #5

Overall, pretest-posttest results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction alone did not significantly improve their District Administered Criterion-Referenced Math Test score results. Comparing students' District Administered Criterion-Referenced Math Test score results with district level derived achievement cut scores puts their performance in perspective. Criterion-referenced Math test scores range from zero to 35 with a mid-point of 17.5. Pretest-posttest results for 4th-grade students who received inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction indicate mean scores (23.42, 22.68) above the mid-point. Scores 14 or below represent the 10th percentile and lower based on school district analysis and result in individual student referral for assessment and special services eligibility. The District Administered Criterion-Referenced Math Test posttest score was in the direction of pretest-posttest decline.

Research Question #6

Overall, results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction used alone group had a higher but not statistically significantly different posttest mean district administered criterion-referenced math test score (22.68) compared to the posttest mean district administered criterion-referenced math test score (20.05) of 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group.

Research Question #7

Inspecting our frequency and percent findings we find that 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction had lower scores on posttest (9, 47%) and improved scores on posttest (10, 53%) that were not significantly different from the reported lower scores on posttest (12, 63%) and improved scores on posttest (7, 37%) for 4th-grade students participating in the inquiry-based hands-on math instruction alone group. While some frequency and corresponding percent variance is noted the lower scores and improved scores comparisons represent near numerical equipoise.

Research Question #8

Overall, pretest-posttest results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction did not significantly improve their absences, tardies, and discipline referrals score results. However, negative posttest absences and tardies *t* test results were in the direction of student improvement in these two behavioral measures with fewer ending of school year absences and tardies. Students' posttest, mean absences scores (6.79) were lower than the school district threshold (10) requiring administrative intervention. Students' posttest, mean tardies scores (8.37) were lower than the school district threshold (15) requiring administrative intervention. Students' posttest, mean discipline referrals scores (0.63) indicate almost no student discipline issues for 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group.

Research Question #9

Overall, pretest-posttest results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction alone did not significantly improve their absences, tardies, and discipline referrals score results. However, negative posttest tardies and discipline referrals *t* test results were in the direction of student improvement in these two behavioral measures with fewer ending of school year tardies and discipline referrals. Students' posttest, mean absences scores (7.37) were lower than the school district threshold (10) requiring administrative intervention. Students' posttest, mean tardies scores (4.58) were lower than the school district threshold (15) requiring administrative intervention. Students' posttest, mean discipline referrals scores (0.16) indicate almost no student discipline issues for 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group.

Research Question #10

Overall, results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction alone group compared to 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted group had a higher but not statistically significantly different mean posttest absences score. Further results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction alone group compared to 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted group had a lower but not statistically significantly different mean posttest tardies score. Finally, results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction alone group compared to 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted group had a lower but not statistically significantly different mean posttest discipline referrals score.

Research Question #11

Overall, results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction alone group mean posttest math Perceptions of Ability Scale for Students percentile rank score (50th-percentile) was at the test median 50th-percentile. Results indicated that 4th-grade students participating in the inquiry-based hands-on math instruction used in combination with web-based computer-assisted math instruction group mean posttest math Perceptions of Ability Scale for Students percentile rank score (40th-percentile) was 10 percentile points below the test median 50th-percentile. Scores ranging from the 40th-percentile to the 60th-percentile indicate that the child likes math and believes that she/he is not experiencing difficulty in performing basic math functions and completing math assignments at school (Boersma & Chapman, 1992).

Discussion

This research attempted to determine if web-based, computer-assisted math instruction, a compelling contemporary intervention, used once each week in combination with a standard-of-care inquiry-based, hands-on math instruction program could improve the math assessment performance of 4th-grade students using the inquiry-based, hands-on math instruction in combination with web-based, computer-assisted math instruction program compared to the math assessment performance of 4th-grade students who participated in the standard of care inquiry-based, hands-on math instruction alone program.

Computer Use and Challenges

When comparing test results of students assessed who were taught using the inquiry-based, hands-on math instruction alone with students who received the inquiry-based, hands-on math instruction in combination with web-based, computer-assisted instruction, results consistently favored the posttest-posttest math assessment ITBS NCE performance comparison of the 4th-grade students who participated in the standard-of-care inquiry-based, hands-on math instruction alone program. As a result, the appropriateness and effectiveness of combining the web-based, computer-assisted math instruction with the inquiry-based, hands-on math instruction for the 4th-grade students in the research schools studied must be called into question. This study's conclusion differs from the findings of many researchers who report that web-based approaches to teaching and learning are here to stay (Collins, Norman, & Schuster, 2001), especially because they seem to help remove some known barriers to learning (Darden, Gilbertson, Kittredge, Lancaster, & Mauldin, 2005; Robson, 2000). On the other hand, implementing technology in the classroom is not without its problems and has added many challenges. Research on improved math outcomes for students using the World-Wide-Web suggests there are some obstacles to successful implementation (Fuks, Gerosa, & Pereira De Lucena, 2002; Juniu, 2006). As a result, some researchers propose that the teen years, middle school, and high school, or even as some purport, the college years (Nwabueze, 2004), may be a more appropriate time to ask students to use technological innovations to improve learning and assessment outcomes. In fact, researchers allege that some math concepts may be too abstract for younger learners to grasp, such as the 4th-grade participants in this study, without extensive exposure, multiple explanations or representations, and concrete models or graphics (Clark, Monk, & Yool, 2007; Barrows, Feltovich, Koschmann, & Myers, 1994; Nwabueze, 2004). Connecting multiple representation or methods seems necessary to deepen understanding and may require even post-elementary level students significantly intensive and direct involvement by a vigilant, perceptive, and conscientious teacher (NCTM, 2003). Consequently, at face value the computer may not necessarily be the technologically preferred tool to sufficiently support the typical child (McCade, 1995). Moreover, there is some consensus that younger children may view using the web and computers as strictly fun, games, and play (Barak, 2004; Freitas, 2006) and, therefore, it may be that many students are actually off-task, that is not completing the math lessons assigned, during times of computer use even though they are busy *playing* in a manner that will strengthen computer skills. Little research has been completed that actually considers on-task behavior in technology-based classrooms (Huang & Wu, 2007). In this study time-on-task and the number of lessons actually completed by the students were not monitored. Considering these dependent variables in future studies will be important for determining how best to incorporate web-based, computer-assisted instruction for elementary age students. To date few studies have examined these measures (Slone, 2007).

Amazingly, however, apart from time-on-task, even time simply spent in front of a computer is a topic that has been given very little consideration (Fabre, Howard, & Smith, 2000). This is why future research should consider some of these critical areas, as well as, focusing on how technology may be used to help students who are facing a variety of abilities, disabilities, and cultural backgrounds and how they may be more successful in school, particularly in math (Anadan, Hammel, Madnick, & Mirza, 2006; Collins, Norman, & Schuster, 2001; Driscoll, 2001; McLoughlin, 1999; Mooij, 2002).

Furthermore, students generally work receptively and more quietly when interacting with a computer, however, learning theory and best classroom practices tell us that students work best, and are more likely to learn, when they are actively engaged (Abrami, Lowerison, Schmid, & Sclater, 2006; Juniu, 2006), are expressive (Neo, 2003), and thinking out loud--part and parcel of the inquiry-based, hands-on instruction that students in the inquiry-based, hands-on math instruction alone group experienced, without interruption, during this research study. Teachers also use out-loud, student feedback and comments to differentially adjust instruction that supports continuous learning (Dalgarno, 2001). Furthermore, an additional concern with computer-assisted learning is that computer programmers could further exasperate the problem by designing computer programs that focus more on the technology, rather than on learner needs (Barrows, Feltovich, Koschmann, & Myers, 1994; Kirschner, 2004). In the end finding a quality designed internet curriculum is perhaps an essential part of the solution to making online instruction work (Chan & Kim, 2004).

In addition, for computer-assisted instruction to be most effective, research shows that the teacher must be active and willing to consistently interact with the students (Bakke & Brandyberry, 2006; Brandt, 1999; Dalgarno, 2001). Unlike a teacher, the computer is somewhat limited in its ability to adjust instruction based on a learner's response in that the computer can only respond in the way it was pre-programmed by the original designer, and therefore, computer programmers face obvious challenges in trying to accurately predict all of the potential student responses (Lim, 2004). Teachers, however, are more likely to adapt and use teachable-moments to a learner's advantage (Healy, Hoyles, & Pozzi, 1995). Unfortunately, when incorporating technology even interaction between the teacher and students is affected and becomes more complicated mainly because many of the traditional roles played by the teacher and students have changed (Lam & Lawrence, 2002; Willett, 2007). Therefore, the roles are no longer well-defined and so are more difficult for researchers to study (Armstrong et al., 2005), but still, just as the teacher makes the difference in traditional approaches to curriculum and instruction, the teacher's contribution will become the determining factor in the overall success of the contemporary, computer-assisted classroom particularly for younger students (Khine & Sing, 2006).

Whereas, some teachers and students prefer to do their work online with computers (Gorder, 2007), other teachers and students actually choose more traditional approaches to teaching and learning, believing textbooks are the preferred method of instruction (Barak, 2004; Toumasis, 2004). Clearly, all future learning environments will rely on technology. In order for teachers to become acquainted with and more accepting of these technologies, effective professional development is needed to help teachers more fully understand the rationales for implementing technology in the classroom and how technology can enhance and be used in conjunction with the best classroom practices and instruction (Hewett & Powers, 2007). It could be that the results of this study were affected by the limited teacher training that took place before and during the course of this study. Therefore, professional development for teachers must include the general theory, rationale, lessons, and skills required by students of all ages--

basic, intermediate, and advanced--so that teachers can feel confident with the integration of technology into their lessons (Cantrell & Knudson, 2006). Furthermore, Hewett and Powers (2007) and other researchers (Robson, 2000) are challenging educators to develop theories of online learning and evaluation that can be used as a starting point so that professional development models can be designed for use in training teachers to be better prepared for impending technological improvements.

In order to best incorporate technology across the curriculum, researchers have consistently cited three fundamental learning approaches, based on the learning theories of three well-known theorists, Dewey, Piaget, and Vygotsky (Cox, Fields, & Rakes, 2006). These are (1) computer use and cooperative learning, (2) computer use and inquiry-based learning, and (3) computer use and differentiated instruction. Two of the aforementioned recommendations, computer use and cooperative learning and computer use and inquiry-based learning, were not included as part of this study, and should respectfully be considered in any future research that incorporates technology into math instructional approaches.

Computer Use and Cooperative Learning

Research over the past thirty years, including the most current studies, all report that students who work cooperatively in small groups (Burns, 2000) are effectively being better prepared for the real world, because it is through a group effort that they will mimic the skills needed to be considered successful in the workforce (Dede, 1990; Freeman & McKenzie, 2002; Leonard, 2001; McCade, 1995; Meckstroth, Smutny, & Walker, 1997; Ou & Sung, 2002; Toumasis, 2004). Indications are that technology can also be used to help improve this process as well (Neo, 2003), so using small groups to solve math problems has been a recommended method for helping students learn math concepts and a way to retain that knowledge for extended periods of time (Healy, Hoyles, & Pozzi, 1995; Kramarski, & Talis, & Weiss, 2006), which is also apparently true when incorporating technology (Abrami, 2001). Traditionally, learning has focused on the individual's attainment of knowledge, while, contemporary theories have moved more towards focusing on group problem solving (Kirschner & Bruggen, 2004; Stahl, 2005). This concept has been extended to include developing group camaraderie online through web-based formats (Ang & Looi, 2000). Since social interaction has often an important part of what teachers and learners do (Brett & Nagra, 2005; Bronack, Riedl, & Tashner, 2006), combining web-based, computer-assisted math instruction, with an individual or small group format, while facilitating cooperative learning, may prove more effective and result in a higher level of learning, above those using whole-group structures (Brandt, 1999; Casto, Taylor, & Walls, 2004) as was done in this research study. Studies that look at technology and cooperative learning simultaneously, as well as, how social communities develop and interact online are uncommon, however (Cho, Gay, Lee, & Stefanone, 2005; Grabowski & Ke, 2007), and thus more research is needed in this area.

Unfortunately, as with any teaching method, with cooperative learning there is no guarantee that participation or learning will occur, so ultimately researchers, parents, students, and other interested parties must continue to rely on the teacher's ability to monitor learning, even while incorporating technology into their classrooms (Friedrich & Hron, 2003). Like cooperative learning, incorporation of technology does not necessarily equate to increased learning (Juniu, 2006; Bachler et al., 2005), so at the end of the day successful integration and learning are often correlated with teacher and student backgrounds, successes, failures, and perceptions (Armstrong et al., 2005). Teachers and students may need ongoing support in how to effectively collaborate online, in order to maximize learning, while at the same time incorporating technology (Maor, 2003).

Computer Use and Inquiry-Based Learning

Some researchers, however, believe that incorporating more contemporary approaches to teaching and learning, such as an inquiry-based approach, will make the difference when implementing technology (Casto, Taylor, & Walls, 2004; Huang, 2002). This is perhaps at least partially because learning environments that are inquiry-based support student learning, even when a variety of learner needs exist (Abrami, Lowerison, Schmid, & Sclater, 2006). Cooner (2005) defines inquiry-based approaches as "teaching and learning processes that encourage students to engage in critically reflective practices, allowing them to question existing knowledge, beliefs, and feelings, which will equip them with the problem-solving skills required to work in highly fluid situations" (p. 375). Even when incorporating technology into lessons, inquiry-based approaches still require a teacher to serve at least as a facilitator and guide to student learning (Maor, 2003; Switzer, 2004). Inquiry-based programs like the math program used in this study, *Investigations*, required students to think more deeply about math problems, form their own conclusions through experimentation and reflection, thus creating their own algorithms and eventually solve the problem (Economopoulos, Mokros, & Russell, 1995). Often inquiry approaches require students to develop questions around very complex issues and to work together to solve them by starting with what they know and constructing knowledge and understanding from there (Sweeney, 2003). To be effective technology will have to be integrated into the inquiry-based process along with other approaches to help make it more efficient and improve learning. More research is called for, however, specifically in the following two areas: (1) studies are needed to determine the exact role technology should play in the modern classroom (Huang & Wu, 2007), and (2) other studies could determine if technology can be infused into an inquiry-based teaching and learning approach, in order to maximize its effectiveness (Ellis, Marcus, & Taylor, 2005).

Computer Use, Differentiated Instruction, and Self-Pacing

One of the most promising learning theories to date is the concept of individualization or what Reis and Renzulli (1997) have termed curriculum modification or differentiation. Two of the advantages of computers are their ability to individualize student instruction and its capability of allowing a student to self-pace (Clark, Monk,

& Yool, 2007). For example, once a student's math abilities or knowledge levels are determined, the computer can plan a series of lessons to help the student maximize learning time, by not spending time on material that the student already knows (Lindquist, 2001). A student's movement through learning activities is, therefore, regulated by successful progress through each lesson (Siegle, 2005). Effectively differentiating the curriculum for a student is actually a difficult process taking teacher skill, effort, and time (Mooij, 2002). Computer programs take these variables into consideration and within seconds adjust the next set of problems to a student's correct or incorrect response (Cook, 2005). Continual advances in technology have made it easier for teachers to individualize curriculum for students of all skill levels (Chan & Kim, 2004). This alone has made technology a fundamental part of instruction in today's classrooms (Oenema, Tan, & Brug, 2005). For example, the computer program used in this study, PassKey, does contain provisions to individualize for students and allow for self-pacing, which has been found to be a positive, motivating factor for students (Kim, Morrison, Tversky, Whang, & Yoon, 2007).

Computer Use and Implementing Innovative Programs

Computer use and technology systems can help foster an innovative learning environment (Chen, Wu, & Yang, 2006), but the exact part technology will play in our classrooms has yet to be determined. Some researchers hypothesize that computers and communication will be a major part of what teachers and students do during the school day (Friedrich & Hron, 2003; Abrami, Lowerison, Schmid, & Sclater, 2006; Sherman, 2000). This is partially why schools of higher learning have been at the forefront in incorporating technology into teaching and learning by testing old held beliefs as to what quality instruction looks, feels, and sounds like, regardless of delivery model (Cooper, 2005; Guidera, 2004). Other researchers support the idea of creating learning communities that are web-based, in order to promote and facilitate learning in numerous, new, and efficient ways (Ang & Looi, 2000). Online learning or e-learning communities and cyber or virtual schools (Berger, 2005; Kirschner & Bruggen, 2004; Siegle, 2005) may in fact become an innovative part of our schools, but the concept has yet to be studied in any great depth (Chen, Wu, & Yang, 2006; Slone, 2007). Hakkinen (2002) and others (Bronack, Riedl, & Tashner, 2006; Ou & Sung, 2002) propose educators create web-based, shared workspaces in which the teacher can post authentic, real-world, and problem-based tasks that can be accessed via a 3-dimensional virtual world online by any student at anytime. This strategy would lend itself to help promote the idea that learning is not limited to individuals or to the school day. Other researchers have turned to instant messaging and video conferencing, in hopes of promoting innovative learning (Bachler et al., 2005), as well as, audio conferencing and text messaging (Chen, Wu, & Yang, 2006). Still, other researchers believe games and simulations, within real-world contexts, are part of the wave of innovations because the possibilities are feasibly limitless and teachers can tap into a student's innate fascination with math and science to discover how they tie into the natural world (Freitas, 2006; Wattenberg & Zia, 2000). All this is made possible because simulations are exciting to students, and their enthusiasm often energizes them to create their own models, which in turn takes their learning to even higher levels (Senge et al., 2000). Digital media production is another method, offered by Willett (2007) as a modern, innovative strategy to engage students in higher levels of learning. Regardless of the teaching approach that a teacher or school endorse, researchers agree that technology will indeed play an essential role in the innovative lessons of tomorrow as they help students prepare for a rapidly changing and unknown future (Bronack, Riedl, & Tashner, 2006; Cox, Fields, & Rakes, 2006).

The Future of Computer Use in our Schools

It has been affirmed and reaffirmed throughout the years that advances in technology will continue to grow exponentially, decrease in costs, and its use in educational settings will continue to increase (Collis & Gervedink, 2005; Collins, Norman, & Schuster, 2001; Dede, 1990; Mulligan, 1984). As a result, future research should fundamentally consider all of the various nuances of how technology can improve curriculum, instruction, and learning. Some researchers also recommend that future research consider how teamwork skills can be developed and assessed by a teacher when delivering lessons using technology (Freeman & McKenzie, 2002). Whereas, others believe studying how students interact with and react to web-based programs is most important (Blommaert, Fischer, & Midden, 2005), especially how the computer could be used to replace traditional or lecture-based teaching formats (Clark, Monk, & Yool, 2007; Land & Surry, 2000).

Many governmental agencies worldwide are convinced that once educators figure out where and how technology fits into curriculum and learning that country will have economic advantages over other nations (Abrami, 2001). As a result, most developed nations continue to vehemently pursue new technologies by spending more and more money (Eisenberg & Johnson, 2002) while simultaneously researching the why's and wherefores of how technology can help teachers and students be more successful during the learning process (Fuks, Gerosa, & Pereira De Lucena, 2002). Research in support of technology use in the classroom is continually being expanded and made current, but compared to other research venues educators are still lagging behind, knowing very little about the benefits of using technology to improve instruction (Driscoll, 2001). Yet, indeed "technology is changing the way we teach and learn" (Abrami, Lowerison, Schmid, & Sclater, 2006, p. 402), and with gradual advances in technology, its use has also increased (Newlin & Wang, 2002), and perceptions of online learning continue to improve (Guidera, 2004) although not by all (Land & Surry, 2000). Knowing how to use technology, how it can help with learning, and its many components and sub-components will allow students to be more prepared for the world of tomorrow (Sherman, 2000). Yet, researchers project that in order to be productive and successful in the world of tomorrow students will need to know how to use technology to their advantage for a variety of unforeseen tasks and purposes that go beyond what is required of students today (Eisenberg & Johnson, 2002). Lessons incorporating technology, therefore, must continue to make strides towards preparing students for the ever-changing world of tomorrow (Switzer, 2004).

Regardless of the stance of educators in the US or abroad, one basic fact remains: technology will play a major role in teaching and learning. Unfortunately, as of yet, the benefits of incorporating technology across the curriculum remain largely untapped (Norris, Soloway, & Sullivan, 2002).

REFERENCES

Abrami, P. C. (2001). Understanding and promoting complex learning using technology. *Educational Research and Evaluation, 7*(2-3), 113-136.

Abrami, P. C., Lowerison, G., Schmid, R. F., & Sclater, J. (2006). Are we using technology for learning? *Educational Technology Systems, 34*(4), 401-425.

Ahlgren, A., & Rutherford, F. J. (1993). Where is project 2061 today? *Educational Leadership.*

Anandan, N., Hammel, J., Madnick, F., & Mirza, M. (2006). A Participatory program evaluation of a system change program to improve access to information technology by people with disabilities. *Disability and Rehabilitation, 28*(19), 1185-1199.

Andrew, L. (2007). Comparison of teacher educators' instructional methods with the constructivist ideal. *The Teacher Educator, 42*(3), 157-184.

Ang, D., & Looi, C. K. (2000). A multimedia-enhanced collaborative learning environment. *Journal of Computer Assisted Learning, 16,* 2-13.

ARC Center (2003). Impact studies: Tri-state student achievement study. Retrieved 2007, from www.comap.com/elementary/projects/arc/

Armstrong, V., Barnes, S., Curran, S., Mills, S., Sutherland, R., & Thompson, I. (2005). Collaborative research methodology for investigating teaching and learning: The use of interactive whiteboard technology. *Educational Review, 57*(4), 457-459.

Baker, D., Street, B., & Tomlin, A. (2006). Navigating schooled numeracies: Explanations for low achievement in mathematics of UK children from low SES background. *Mathematical Thinking and Learning, 8*(3), 287-307.

Bakke, S. A., & Brandyberry, A. A. (2006). Mitigating negative behaviors in student project teams: An information technology solution. *Journal of Information Systems Education, 17*(2), 195209. Retrieved June 16, 2008, from The H.W. Wilson Company/WilsonWeb.

Barak, M. (2004). The use of computers in technological studies: Significant learning or superficial activity? *Journal of Computers in Mathematics and Science Teaching, 23*(4), 329-346.

Barnett, C., Briars, D., Charles, R., Crown, W., Johnson, M., Leinwand, S., & Van de Walle, J. (2001). *Scott Foresman—Addison Wesley Math* (Millennium ed). Illinois: Scott Foresman.

Barrows, H., Feltovich, P., Koschmann, T., & Myers, A. (1994). Using technology to assist in realizing effective learning and instruction: A principled approach to the use of computers in collaborative learning. *The Journal of the Learning Sciences, 3*(3), 227-264.

Batchelder, J. S. & Rachal, J. R. (2000). Efficacy of a computer-assisted instruction program in a prison setting: An experimental study. *Adult Education Quarterly, 50*(2), 120-134.

Berger, S. (2005). The Evolution of Technology: A decade of surfing the net. *Understanding Our Gifted: Technology, 17*(4), 3-5.

Berk, D., & Martin, W. G. (2001). The Cyclical relationship between research and standards: The case of principles and standards for school mathematics. *School Science and Mathematics, 101*(6), 328-339.

Berk, D., & Olson, M. (2001). Two mathematicians' perspectives on standards: Interviews with Judith Roitman and Alfred Manaster. *School Science and Mathematics, 101*(6), 305-309.

Berle-Carman, M., Mokros, J., O'Neil, K., & Rubin, A. (2007). Learning operations: Invented strategies that work. *Investigations in Number, Data, and Space*. Retrieved October 15, 2007, from http://investigations.terc.edu/impact/impact-studies/strategiesthatwork.cfm

Berle-Carman, M., Mokros J., Rubin, A., & Wright, T. (1994). Full-year pilot grades 3 and 4. *Investigations in Number, Data, and Space*. Retrieved October 15, 2007, from http://investigations.terc.edu/impact/impact-studies/pilot3-4.cfm

Berlin, D.F., & Hillen, J.A. (1994). Making connections in math and science: Identifying student outcomes. *School Science and Mathematics, 94*(6), 283-290.

Bielefeldt, T. (2005). Computers and student learning: Interpreting the multivariate analysis of PISA 2000. *Journal of Research on Technology in Education, 37*(4), 339-347.

Bishop, M., & Slagter van Tryon, P. J. (2006). Identifying "E-MMEDIACY" strategies for web-based instruction. *The Quarterly Review of Distance Education, 7*(1), 49-62.

Blommaert, F. J., Fischer, A. R., & Midden, C. J. (2005). Monitoring and evaluation of time delay. *International Journal of Human-Computer Interaction, 19*(2), 163-180.

Boersma, Frederic J., & Chapman, James W. (1992). *Perception of ability scale for students*. Los Angeles, CA. Western Psychological Services.

Boris, G., & Reisetter, M. (2004). What works: Student perceptions of effective elements in online learning. *The Quarterly Review of Distance Education, 5*(4), 277-291.

Bottge, B., Kwon, J., Rueda, E., & Serlin, Y. (2007). Shrinking achievement differences with anchored math problems: challenges and possibilities. *The Journal of Special Education*, *41*(1), 31-49.

Boys, C., Kosciolek, S., Lemkuil, A., Spicuzza, R., Teelucksingh, & Ysseldyke, J. (2003). Using a curriculum-based instructional management system to enhance math achievement in urban schools. *Journal of Education for Students Placed at Risk, 8*(2), 247-265.

Brandt, S. (1999). The use of computer-assisted cooperative learning classroom environment to teach job skills to adults. *Journal of Educational Technology Systems, 28*(1), 97-104.

Brett, P., & Nagra, J. (2005). An investigation into students' use of a computer-based social learning space: Lessons for facilitating collaborative approaches to learning. *British Journal of Educational Technology, 36*(2), 281-292.

Broderick, A., Mehta-Parekh, H., & Reid, W. (2005). Differentiating instruction for disabled students in inclusive classrooms. *Theory Into Practice, 44*(3), 194-202.

Bronack, S., Riedl, R., & Tashner, J. (2006). Learning in the zone: A social constructivist framework for distance education in a 3-dimensional virtual world. *Interactive Learning Environments, 14*(3), 219-232.

Brug, J., Ph.D., Oenema, A., Ph.D., & Tan, F., Ph.D. (2005). Short-term efficacy of a web-based computer-tailored nutrition intervention: Main effects and mediators. *The Society of Behavioral Medicine, 29*(1), 54-63.

Buchholz, D., & Cooke, B. D. (2005). Mathematical communication in the classroom: A teacher makes a difference. *Early Childhood Education Journal, 32*(6), 365-369.

Bullard, B. (2005). Catching the tail of the comet: Technology in the classroom. *Understanding Our Gifted: Technology, 17*(4), 9-12.

Burkette, L., & Kariuki, P. (2007, November). *The effects of teacher mediation on kindergarten students' computer-assisted mathematics learning.* Paper presented at a meeting of the Annual Conference of the Mid-South Educational Research Association, Hot Springs, AR.

Burns, M. (2000). *About Teaching Mathematics A K-8 Resource* (Second ed.). Sausalito, CA: Math Solutions Publications. (Original work published 2000)

Bush, G. (2006). Learning about learning from theories to trends. *Teacher Librarian, 34*(2), 14-18.

Butler, F., Hudson, P., & Miller, S. P. (2006). Adapting and merging explicit instruction within reform based mathematics classrooms. *American Secondary Education, 35*(1), 19-32.

Capizzi, A. M., Fuchs, D., Fuchs, L. S., Hamlet, C. L., Powell, S. R., & Seethaler, P. M. (2006). The effects of computer-assisted instruction on number combination skill in at-risk first graders. *Journal of Learning Disabilities, 39*(5), 467-475.

Canter, L., Gardner, J., Schweder, W., & Wissick, C. (2003). Enhancing interdisciplinary instruction in general and special education. *Remedial & Special Education, 24*(3), 161-172.

Cantrell, P., & Knudson, M. S. (2006). Using technology to enhance science inquiry in an outdoor classroom. *Type II Uses of Technology in Education,* 7-18. Retrieved July 13, 2008, from http://www.haworthpress.com/web/CITS

Casto, D. J., Taylor, L. M., & Walls, R. T. (2004). Tools, time and strategies for integrating technology across the curriculum. *Journal of Constructivist Psychology, 17,* 121-136.

Caverly, D. C., & MacDonald, L. (1999). Techtalk: Technology and developmental math. *Journal of Developmental Education, 22*(3), 32-33.

Cawley, J. F., & Foley, T. E. (2002). Connecting math and science for all students. *Teaching Exceptional Children, 34*(4), 14-19.

Chan, W., & Kim, D.H. (2004). Towards greater individualization and process-oriented learning through electronic self-access: Project "e-daf". *Computer Assisted Language Learning, 17*(1), 83-108.

Chen, C., & Liu, P. (2007). Personalized computer-assisted mathematics problem-solving program and its impact on Taiwanese students. *Journal of Computers in Mathematics and Science Teaching, 26*(2), 105-121.

Chen, C. C., Wu, J. & Yang, S. C. (2006). *The efficacy of online cooperative learning systems.* Retrieved June 16, 2008 from http://www.emarldinsight.com.leo.lib.unomaha.edu

Chernish, W. N., DeFranco, A. L., Dooly, K. E., & Lindner, J. R. (2005). Does it matter? Analyzing the results of three different learning delivery methods. *The Quarterly Review of distance Education, 6*(2), 87-95.

Cho, H., Gay, G., Lee, J.-S., & Stefanone, M. (2005). Development of computer-supported collaborative social networks in a distributed learning community. *Behavior & Information Technology, 24*(6), 435-447.

Chute, R., & Miksad, J. (1997). Computer assisted instruction and cognitive development in preschoolers. *Child Study Journal, 27*(3), 237-254.

Clark, A. M., Monk, J., & Yool, S. R. (2007). GIS pedagogy, web-based learning and student achievement. *Journal of Geography in Higher Education, 31*(2), 225-239.

Clune, W. (1998). The 'standards wars' in perspective. *Teachers College Record. 100*(1), 144-149.

Collins, B. C., Norman, J. M., & Schuster, J. W. (2001). Using an instructional package including video technology to teach self-help skills to elementary students with mental disabilities. *Journal of Special Education Technology, 16*(3), 5-18. Retrieved June 16, 2008, from The H.W. Wilson Company/WilsonWeb.

Collis, B., & Gervedink Nijhuis, G. (2005). How can academics stay in control? *British Journal of Education Technology, 36*(6), 1035-1049. Retrieved June 16, 2008, from The H.W. Wilson Company/WilsonWeb.

Cook, N. (2005). Using time-saving technology to facilitate differentiated instruction. *Understanding Our Gifted: Technology, 17*(4), 16-19.

Cooner, T. (2005). Dialectical constructivism: Reflections on creating a web-mediated enquiry-based learning environment. *Social Work Education, 24*(4), 375-390.

Cooper, B. (2005). Online courses: Connecting with distance learning. *Understanding Our Gifted: Technology, 17*(4), 13-15.

Conrad, D., & Kanuka, H. (2003). The name of the game why distance education says it all. *The Quarterly Review of Distance Education, 4*(4), 385-393.

Cordon, L. A., & Day, J. D. (1993). Static and dynamic measures of ability: An experimental comparison. *Journal of Educational Psychology, 85*(1), 75-82.

Cox, K. E., Fields, V. S., & Rakes, G. C. (2006). The influence of teachers' technology use on instructional practices. *Journal of Research on Technology in Education, 38*(4), 409-424.

Dalgarno, B. (2001). Interpretations of constructivism and consequences for computer assisted learning. *British Journal of Educational Technology, 32*(2), 183-194.

Darden, P. M., Gilbertson, B. O., Kittredge, D., Lancaster, C. J., & Mauldin, M. P. (2005). How we changed from paper to online education: Teaching immunization delivery and evaluation. *Medical Teacher, 27*(8), 682-685.

Davis, J., Leonard, J., & Sidler, J. (2005). Cultural relevance and computer-assisted instruction. *Journal of Research on Technology in Education, 37*(3), 263-284.

Davitt, R. M. (2000). The evolutionary character of mathematics. *Mathematics Teacher, 93*(8), 692-694.

Deatline-Buchman, A. Griffin, C., Jitendra, A., & Sczesniak, E. (2007). Mathematical word problem solving in third-grade classrooms. *The Journal of Educational Research, 100*(5), 283-302.

de Freitas, S. I. (2006). Using games and simulations for supporting learning. *Learning, Media and Technology, 31*(4), 343-358.

Dede, C. J. (1990). The evolution of distance learning: Technology mediated interactive learning. *Journal of Research on Computing in Education, 22*(1), 247-263. Retrieved June 16, 2008, from Academic Search Premier: http://web.ebscohost.com.leo.lib.unomaha.edu

DeSimone, J., & Parmar, R. (2006). Issues and challenges for middle school mathematics teachers in inclusion classrooms. *School Science and Mathematics, 106*(8), 338-348.

DeSimone, L., Phillips, K., & Smith, T. (2007). Does policy influence mathematics and science teachers' participation in professional development? *Teachers College Record, 109*(5), 1086-1122.

Dimino, J. A. (2007). Bridging the gap between research and practice. *Journal of Learning Disabilities, 40*(2), 183-189.

Ding, M., Kulm, G., Li, X., & Piccolo, D. (2007). Teacher interventions in cooperative-learning mathematics classes. *The Journal of Educational Research, 100*(3), 162-175.

Ding, C., Richardson, L., & Song, K. (2006). Do mathematical gender differences continue? A longitudinal study of gender difference and excellence in mathematics performance in the US *Educational Studies, 40*(3), 279-295.

Doe, C. G. (2005). A look at ... products for math teachers. *MultiMedia & Internet@Schools, 12*(4).

Driscoll, M. P. (2001). Computers for what? Examining the roles of technology in teaching and learning. *Educational Research and Evaluation, 7*(2-3), 335-349.

Dugdale, S., Guerrero, S., & Walker, N. (2004). Technology in support of middle grade mathematics: What have we learned? *The Journal of Computers in Mathematics and Science Teaching, 23*(1), 5-20.

Duggan, M., Husman, J., Pennington, N., & Wadsworth, L. (2007). Online mathematics achievement: Effects of learning strategies and self-efficacy. *Journal of Developmental Education, 30*(3), 6-14.

DuPaul, G. J. & Ota, K. R. (2002). Task engagement and mathematics performance in children with attention-deficit hyperactivity disorder: Effects of supplemental computer instruction. *School Psychology Quarterly, 17*(3), 242-257.

Economopoulos, K., Mokros, J., & Russell, S. (1995). *Beyond Arithmetic Changing Mathematics in the Elementary Classroom.* Parsippany, NJ: Dale Seymour Publications. (Original work published 1995)

Edmonds, K. A., & Li, Q. (2005). Mathematics and at-risk adult learners: Would technology help? *Journal of* Eisenberg, M. B., & Johnson, D. (2002). Learning and teaching information technology -- computer skills in context. *ERIC Digest.* Retrieved July 13, 2008, from http://www.ericdigests.org/2003-1/skills.htm

Ellis, R. A., Marcus, G., & Taylor, R. (2005). Learning through inquiry: student difficulties with online course-based material. *Journal of Computer Assisted Learning, 21,* 239-252.

Ellis, W., Kennedy, P., & Oien, J. (2007). Mastery with meaning: Access to mathematics online. *Mathematics and Computer Education, 41*(2), 118-126.

Elmendorf, H. G. (2006, Nov/Dec). Learning through teaching: A new perspective on entering a discipline. *Change,* 37-41.

Engelbrecht, J., & Harding, A. (2005). Teaching undergraduate mathematics on the internet. *Educational Studies in Mathematics. 58*, 235-252.

Fabre, J., Howard, S., & Smith, R. (2000). Designing time at the user interface. *Behavior & Information Technology, 19*(6), 451-463.

Fahsl, A. (2007). Mathematics accommodations for all students. *Intervention in School and Clinic, 42*(4), 198-203.

Faux, R., & FitzPatrick, S. B. (2002, April). *An exploratory study of the implementation of an interactive learning system in two eighth grade mathematics classes.* Paper presented at the American Education Research Association conference, New Orleans, LA.

Fennema, E., & Sherman, J. A. (1976). [Fennema-Sherman Mathematics Attitudes Scales]. Unpublished raw data, University of Wisconsin.

Ferrini-Mundy, J. (2001). Introduction: Perspectives on principles and standards for school mathematics. *School Science and Mathematics, 101*(6), 277-279.

Foshay, R., & Perez, S. (2002). Adding up the distance: Can developmental studies work in a distance learning environment? *The H.W. Wilson Company/WilsonWeb, 29*(8).

Foster, P. N. (2005). Technology in the standards of other school subjects. *The Technology Teacher,* 17-21.

Freeman, M., & McKenzie, J. (2002). SPARK, a confidential web-based template for self and peer assessment of student teamwork: Benefits of evaluating across different subjects. *British Journal of Educational Technology, 33*(5), 551-569.

Friedrich, H., & Hron, A. (2003). A review of web-based collaborative learning: factors beyond technology. *Journal of Computer Assisted Learning, 19,* 70-79.

Fuks, H., Gerosa, M., & Pereira De Lucena, C. (2002). The development and application of distance learning courses on the internet. *Open Learning, 17*(1), 23-28.

Fuller, J. L. (2001). *An integrated hands-on inquiry based cooperative learning approach: The impact of the PALMS approach on student growth.*

Gagnon, J., & Maccini, P. (2007). Teacher-reported use of empirically validated and standards-based instructional approaches in secondary mathematics. *Remedial and Special Education, 28*(1), 43-56.

Galbraith, M., & Jones, M. (2006). The art and science of teaching developmental mathematics: Building perspective through dialogue. *Journal of Developmental Education, 30*(2), 20-27.

Goodrow, A. (2007). Modes of teaching and ways of thinking. *Investigations in Number, Data, and Space.* Retrieved October 15, 2007, from http://investigations.terc.edu/impact/impact-studies/modesofteaching.cfm

Gorder, L. M. (2007). Creating classrooms of the future: Connecting classrooms with one-to-one computing. *The Delta Kappa Gamma Bulletin,* 19-38.

Grabowski, B., & Ke, F. (2007). Game playing for math learning: Cooperative or not? *British Journal of Educational Technology, 38*(2), 249-259.

Guidera, S. G. (2004). Perceptions of the effectiveness of online instruction in terms of the seven principles of effective undergraduate education. *Educational Technology Systems, 32*(2 & 3), 139-178.

Gunter, P., & Scheetz, N. (2004). Online versus traditional classroom delivery of a course in manual communication. *Exceptional Children, 71*(1), 109-120.

Hall, T. (2002). *Differentiated instruction.* Wakefield, MA: National Center on Accessing the General Curriculum. Retrieved October 8, 2007, from http://www.cast.org/publications/ncac/ncac_diffinstruc.html

Harlacher, J. E., Merrell, K. W., & Roberts, N. E. (2006). Teaching exceptional children classwide interventions for students with ADHD. *Council For Exceptional Children, 39*(2), 6-12.

Hart, E. W., Keller, B. A., & Martin, W. G. (2001). Illuminating NCTM's principles and standards. *School Science and Mathematics. 101*(6), 292-304.

Harwell, M., & Subkoviak, M.J. (1995). Review of the perception of ability scale for students (PASS). In J. C. Conoley and J.C. Impara, *The twelfth mental measurements.* Lincoln, NE: Buros Institute of Mental Measurements.

Hazzan, O. (2003). Prospective high school mathematics teachers' attitudes toward integrating computers in their future teaching. *Journal of Research on Technology in Education, 35*(2), 213-225.

Healy, L., Hoyles, C., & Pozzi, S. (1995). Making sense of groups, computers, and mathematics. *Cognition and Instruction, 13*(4), 505-523.

Hewett, B. L., & Powers, C. E. (2007). Guest editors' introduction: Online teaching and learning: Preparation, development, and organizational communication. *Technical Communication Quarterly, 16*(1), 1-11.

Hollowman Jr., H. L. & Warren, L. L. (2005). On-line instruction: Are the outcomes the same? *Journal of Instructional Psychology, 32*(2), 148-151.

Hong, E., Stewart, I., & Strudler, N. (2004). Development and validation of an instrument for student evaluation of the quality of web-based instruction. *The American Journal of Distance Education, 18*(3), 131-150.

Hoover, J., & Patton, J. (2004). Differentiating standards-based education for students with diverse needs. *Remedial and Special Education, 25*(2), 74-78.

Hoskins, S., & Van Hooff, J. (2005). Motivation and ability: Which students use online learning and what influence does it have on their achievement? *British Journal of Educational Technology, 36*(2), 177-192.

Huang, H. M. (2002). Toward constructivism for adult learners in online learning environments. *British Journal of Educational Technology, 33*(1), 27-37.

Huang, Y. L., & Wu, H. K. (2007). Ninth-grade student engagement in teacher-centered and student-centered technology-enhanced learning environments. *Wiley InterScience,* 727-749.

Imamoglu, Y., & Kahveci, M. (2007). Interactive learning in mathematics education: Review of recent literature. *Journal of Computers in Mathematics and Science Teaching, 26*(2), 137-153.

Imhausen, A. (2006). Ancient egyptian mathematics: New perspectives on old sources. *The Mathematical Intellingencer. 28*(1), 19-27.

Investigations. Retrieved January 20, 2008, from http://investigations.scottforesman.com

Iowa Test of Basic Skills (ITBS), Forms K, L, and M. (1996). The Riverside Publishing Company, Chicago, IL.

Irish, C. (2002). Using peg- and keyword mnemonics and computer-assisted instruction to enhance basic multiplication performance in elementary students with learning and cognitive disabilities. *Journal of Special Education Technology, 17*(4), 29-40.

Jacobson, E. (2006). Computer homework effectiveness in developmental mathematics. *Journal of Developmental Education, 29*(3), 2-8.

Jones, J., Palmer, R. L., Reid, J. B., & Whitlock, J. (1973). Computer-assisted-instruction performance of student pairs as related to individual differences. *Journal of Educational Psychology, 65*(1), 65-73.

Juniu, S. (2006). Use of technology for constructivist learning in a performance assessment class. *Measurement in Physical Education and Exercise Science, 10*(1), 67-79.

Khine, M., & Sing, C. (2006). An analysis of interaction and participation patterns in online community. *Educational Technology & Society, 9*(1), 250-261.

Kim, S., Morrison, J., Tversky, B., Whang, S., & Yoon, M. (2007). The effect of animation on comprehension and interest. *Journal of Computer Assisted Learning, 23,* 260-270.

Kirschner, P. A. (2004). Introduction to part II of the special issue: Design, development and implementation of electronic learning environments for collaborative learning. *Educational Technology Research & Development, 52*(4), 37.

Kirschner, P. A., Ph.D., & Van Bruggen, J., Ph.D. (2004). Learning and understanding in virtual teams. *CyberPsychology & Behavior, 7*(2), 135-139.

Kool, M. (2003). An extra student in your classroom: How the history of mathematics can enrich interactive mathematical discussions at primary school. *Mathematics in School,* 19-22.

Kramarski, B., Talis, S., & Weiss, I. (2006). Effects of multimedia environments on kindergarten children's mathematical achievements and style of learning. *Educational Media International, 43*(1), 3-17.

Kulik, J. A. (2003, November). *Instructional technology and school reform models*. Paper presented at a meeting of the Office of Evaluations & Examinations, Ann Arbor, MI.

Kulm, G. (2006). Reflections on research in science and mathematics education. *School Science and Mathematics, 106*(8), 324-325.

Kulm, G. (2007) Learning from the history of mathematics and science education. *School Science and Mathematics, 107*(1), 368.

Lam, Y., & Lawrence, G. (2002). Teacher-student role redefinition during a computer-based second language project: Are computers catalysts for empowering change? *Computer Assisted Language Learning, 15*(3), 295-315.

Lamb, A., & Johnson, L. (2006). Flash: Engaging learners through animation, interaction, and multimedia. *Teacher Librarian, 33*(4).

Land, S.M., & Surry, D.W. (2000). Strategies for motivating higher education faculty to use technology. *Innovations in Education and Training International, 37*(2), 145-153.

Landel, C., & Nelson, G. (2007). A collaborative approach for elementary science. *Educational Leadership,* 72-75.

Lavooy, M. J., Newlin, M. H., & Wang, A. Y. (2005). An experimental comparison of conventional and web-based instructional formats. *North American Journal of Psychology, 7*(2), 327-335.

Leonard, J. (2001). How group composition influenced the achievement of sixth-grade mathematics students. *Mathematical Thinking and Learning, 3*(2/3). Retrieved June 16, 2008, from EBSCO HOST Research Databases: http://web.ebscohost.com.leo.lib.unomaha.edu

Lim, B. R. (2004). Challenges and issues in designing inquiry on the web. *British Journal of Educational Technology, 35*(5), 627-643.

Lindquist, M. M. (2001). NAEP, TIMSS, and PSSM: Entangled influences. *School Science and Mathematics, 101*(6), 286-291.

Mann, E. (2006). Creativity: The essence of mathematics. *Journal for the Education of the Gifted, 30*(2), 236-260.

Maor, D. (2003). The teacher's role in developing interaction and reflection in an online learning community. *Education Media International,* 127-137.

Mauch, E., & McDermott, M. (2007). Can elementary mathematics textbooks be improved to facilitate student understanding of mathematics? *Mathematics and Computer Education, 41*(2), 127-135.

McCade, J. (1995). Educational reform and technology education. *The Technology Teacher,* 31-39.

McLoughlin, C. (1999). Culturally responsive technology use: Developing an on-line community of learners. *British Journal of Educational Technology, 30*(3), 231-243. Retrieved June 16, 2008, from The H.W. Wilson Company/WilsonWeb.

McPherson, P., & Murray, D. E. (2006). Scaffolding instruction for reading the web. *Language Teaching Research, 10*(2), 131-156.

Meckstroth, E. A., Smutny, J. F., & Walker, S. Y. (1997). M. Lisovskis. *Teaching Young Gifted Children in the Regular Classroom: Identifying, Nurturing, and Challenging Ages 4-9.* Minneapolis, MN: Free Spirit Publising Inc. (Original work published 1997)

Merrill, C. (2001). Integrated technology, mathematics, and science education: A quasi-experiment. *Journal of Industrial Teacher Education, 38*(3), 45-61.

Mishra, Sanjaya. (2005). Colloquium learning from the online learners. *British Journal of Education Technology,* 23(3), 569-574.

Mokros, J. (2000). Children's understanding of whole number operations. *Investigations in Number, Data, and Space.* Retrieved October 15, 2007, from http://investigations.terc.edu/impact/impact-studies/whole_numb_ops.cfm

Mooij, T. (2002). Designing a digital instructional management system to optimize early education. *ETR&D, 50*(4), 11-23.

Moores, D. F. (2004). No child left behind: The good, the bad, and the ugly. *American Annals of the Deaf, 148*(5), 347-348.

Mulcahy, R. (2001). The design process for PLATO(R) math problem solving. *The H.W. Wilson Company/WilsonWeb, 45*(2).

Mulligan, J. G. (1984). A cost function for computer-assisted programmed instruction. *Journal of Economic Education,* 275-281.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics,* Reston, VA: Author.

National Science Foundation. (2007). Developing the curriculum. *Investigation in Number, Data, and Space.* Retrieved October 15, 2007, from http://investigations.terc.edu/developing/

Neo, M. (2003). Developing a collaborative learning environment using a web-based design. *Journal of Computer Assisted Learning, 19,* 462-473.

Newlin, M. H., & Wang, A. Y. (2002). *Integrating Technology and Pedagogy: Web Instruction and Seven Principles of Undergraduate Education.*

Norris, C., Soloway, E., & Sullivan, T. (2002). Examining 25 years of technology in US education. *Communications of the ACM, 45*(8), 15-18.

Nwabueze, K. K. (2004). Computers in abstract algebra. *International Journal of Mathematical Education in Science and Technology, 35*(1), 39-49.

Ou, S. C., & Sung, W. T. (2002). Web-based Learning in the computer-aided design curriculum. *Journal of Computer Assisted Learning, 18*, 175-187.

Park, J., & Slykhuis, D. (2006). Correlates of achievement with online and classroom-based MBL physics activities. *Journal of Computers in Mathematics and Science Teaching, 25*(2), 147-163.

PassKey. Retrieved January 20, 2008, from www.passkeylearning.com

PassKey helps students achieve standards every step of the way. (1999). *THE Journal, 27*(3), 116.

PassKey helps West Virginia students achieve mastery. (2000). *THE Journal, 28*(3), 100-101.

Perin, D. (2004). Remediation beyond developmental education: The use of learning assistance centers to increase academic preparedness in community colleges. *Community College Journal of Research and Practice, 28*, 559-582.

PLATO Learning, Inc. (1994). *An annotated bibliography of reviews, technical paper #1*. Retrieved July 13, 2006, from http://www.PLATO.com

PLATO Learning, Inc. (2002). *An overview of the research base of PLATO technical paper #12.* Retrieved July 13, 2006, from http://www.PLATO.com

PLATO Learning, Inc. (2003). *A guide for implementing technology or, now that we've got them, what do we do with them?, technical paper #5*. Retrieved July 13, 2006, from http://www.PLATO.com

PLATO Learning, Inc. (2003). *Guidelines for evaluating PLATO learning programs, technical paper #2.* Retrieved July 13, 2006, from http://www.PLATO.com

PLATO Learning, Inc. (2003). *School improvement and PLATO learning, technical paper #14*. Retrieved July 13, 2006, from http://www.PLATO.com

PLATO Learning, Inc. & Kirkley, J. (2003). *Principles for teaching problem solving, technical paper #4.* Retrieved July 13, 2006, from http://www.PLATO.com

PLATO Learning, Inc., & Quinn, D. (2003). In R. Foshay, *PLATO web learning network for 8th grade math in seven Iowa schools*. Retrieved July 13, 2006, from http://www.PLATO.com

Research Advisory Committee (2001). Supporting communities of inquiry and practice. *Journal for Research in Mathematics Education, 32*(5), 444-447.

Reilly, R. (2004, September). Technology-based mathematics: Tools and content for teaching, assessment, and accountability. *MultiMedia & Internet@Schools, 11*(5).

Reis, S. M., & Renzulli, J. S. (1997). *The Schoolwide Enrichment Model: A How-To Guide for Educational Excellence* (Second ed.). Mansfield Center, CT: Creative Learning Press, Inc. (Original work published 1997)

Remmert, V. R. (2004). What do you need a mathematician for? Martinus Hortensius's "speech on the dignity and utility of the mathematical sciences" (Amsterdam 1634). D. E. Rowe (Ed.), *The Mathematical Intelligencer, 26*(4), 40-46.

Rennert-Ariev, P., & Valli, L. (2002). New standards and assessments? Curriculum transformation in teacher education. *Journal of Curriculum Studies, 34*(2), 201-225.

Renzulli, J. (2005). Neglecting creativity. *Education Week, 24*(38).

Robson, J. (2000). Evaluating on-line teaching. *Open Learning, 15*(2), 151-172.

Rogers, K. B. (2002). *Re-forming Gifted Education: Matching the Program to the Child.* Scottsdale, AZ: Great Potential Press, Inc.

Russell, S. (2007). The re-vision of investigations. *Investigations in Number, Data, and Space*. Retrieved October 15, 2007, from http://investigations.terc.edu

Salvia, J., & Ysseldyke, J.E. (2004). *Assessment in Special and Inclusive Education* (Ninth ed.). New York: Houghton Mifflin Company.

Scott Foresman-Addison Wesley. Retrieved January 20, 2008, from www.scottforesman.com

Sherman, L. W., Ph.D. (2000). Postmodern constructivist pedagogy for teaching and learning cooperatively on the web. *CyberPsychology & Behavior, 3*(1), 51-57.

Shyu, H.-Y. (1997). Anchored instruction for Chinese students: Enhancing attitudes toward mathematics. *International Journal of Instructional Media, 24*(1), 55-62.

Siegle, D. (2005). The internet as an aide to teaching the gifted. *Understanding Our Gifted: Technology, 17*(4), 6-8.

Silberman, R. (2003). An art or a science? *Journal of Education, 183*(2), 11-47.

Slone, D. J. (2007). The impact of time constraints on internet and web use. *Journal of the American Society for Information Science and Technology, 58*(4), 508-517.

Smith, I. D. (1973). Impact of computer-assisted instruction on student attitudes. *Journal of Educational Psychology, 64*(3), 366-372.

Stahl, G. (2005). Group cognition in computer-assisted collaborative learning. *Journal of Computer Assisted Learning, 21,* 79-90.

Standards for School Mathematics. *School Science and Mathematics, 101*(6), 292-304.

Stoik, J. H. (2001). Technology's role in collaboration. *Community College Journal of Research & Practice, 25*(1), 37-46.

Subkoviak, M. J. (1995). Review of the Perception of Ability Scale for Students (PASS). In J. C. Conoley and J.C. Impara (Eds.), *The twelfth mental measurements.* Lincoln, NE: Buros Institute of Mental Measurements.

Summers, J. J., Waigandt, A., & Whittaker, T. A. (2005). A comparison of student achievement and satisfaction in an online versus a traditional face-to-face statistics class. *Innovative Higher Education, 29*(3), 233-250.

Sweeney, D. (2003). *Learning Along the Way.* Portland, Maine: Stenhouse Publishers. (Original work published 2003)

Switzer, J. S. (2004). Teaching computer-mediated visual communication to a large section: A constructivist approach. *Innovative Higher Education, 29*(2), 89-101.

Tillman, S. (2001). Focus on math. *T.H.E. Journal, 28*(9).

Timmerman, M. A. (2000). Learning in the context of a mathematics teacher education course: Two case studies of elementary teachers' conceptions of mathematics, mathematics teaching and learning, and the teaching of mathematics with technology. *Journal of Technology and Teacher Education, 8(3)*, 247-258.

Third International Mathematics and Science Study (TIMMS). (2003). Retrieved, 2007, from http://nces.ed.gov.timss/

Toumasis, C. (2004). Cooperative study teams in mathematics classrooms. *International Journal of Mathematical Education in Science and Technology, 35*(5), 669-679.

Willett, R. (2007). Technology, pedagogy and digital production: A case study of children learning new media skills. *Learning, Media and Technology, 32*(2), 167-181.

Winebrenner, S. (2001). *Teaching Gifted Kids in the Regular Classroom: Strategies and Techniques Every Teacher Can Use to Meet the Academic Needs of the Gifted and Talented.* Minneapolis, MN: Free Spirit Publishing Inc.

Xin, Y. (2007). Word problem solving tasks in textbooks and their relation to student performance. *The Journal of Educational Research, 100*(6), 347-359.

Appendix A. Research School District Letter of Support

Appendix B. Letter Approving Research from University of Nebraska Medical Center/University of Nebraska at Omaha Combined Institutional Review Board for the Protection of Human Subjects