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Multimedia mathematics intervention for math-delayed middle school students

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MULTIMEDIA MATHEMATICS INTERVENTION FOR MATH-DELAYED MIDDLE SCHOOL STUDENTS

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The Department of Educational Theory, Policy, and Practice

by
Lisa L. Stokes
B. A. McNeese State University, 1980
M. Ed. McNeese State University, 1981
May 2008
DEDICATION

I would like to thank my parents, W. P. “Whit” and Sybil Stokes, for instilling in me a love for learning and introducing me to Louisiana State University (LSU) in the early 1960’s when my father was a graduate student there. Some of my fondest early childhood recollections include taking the Tiger Train to Tiger Town with my mother or being piggy-backed by my older brother, Perry, with my sisters Sally and Diane in tow, through the field in which the Pete Maravich Assembly Center now stands. These experiences kindled my desire to obtain a degree from LSU, which has reached fruition “forty-something” years later.

My sons, John Monteith and Will Monteith, also deserve credit as they have been a constant source of strength and encouragement throughout this experience. John, an LSU graduating senior at this writing, always took time out of his busy schedule to shop the bookstores for my text books, make deliveries to professors, or even jump start my car on a cold, dark night in the pouring rain. Will, a sophomore at SOWELA Technical College at this writing, provided me with support on the home front, changing the oil in my car, giving bear hugs when needed, and sending flowers with purple and gold ribbons to provide encouragement.

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ABSTRACT

The purpose of this study is to determine if the Sharpening Math Skills Lab technology-mediated mathematics instructional practices for math-delayed middle school students have positive effects on their mathematics achievement and spatial visualization ability and to gauge student engagement in learning, implementation of the principles of instructional design, and attitudes toward mathematics instruction. The results of a recent meta-analysis report a range of significantly positive to significantly negative effect sizes which establish a need for further evaluation of academic achievement utilizing technology-mediated mathematics programs at the middle school level (Slavin, Lake, & Groff, 2007). The literature (Moreno & Mayer, 2000) also suggests examining the principles of multimedia instructional design as they relate to programs such as those utilized in the Sharpening Math Skills Lab. The need for testing for relationships between student spatial visualization and problem solving ability (Wheatley, 1991), student attitudes and motivation toward mathematics (Tapia & Marsh, 2004), and students’ behavior while engaged in multimedia learning activities has also been established in the literature.

This quasi-experimental study compares academic achievement of 109 southwest Louisiana 6th, 7th, and 8th grade students in one school who participated in a treatment program of technology-mediated remedial math instruction with 162 - 6th, 7th, and 8th grade students from two other schools in the same district who received traditional classroom mathematics instruction. The experimental group attended the Sharpening Math Skills Lab 45 minutes per day utilizing FASTTMath software and iSucceed software with individual assistance provided by the lab facilitator and math teacher.

Measurement instruments include Scantron Performance and Achievement Series tests, Wheatley Spatial Ability Test (WSAT) (Wheatley, 1996), and Attitudes Toward Math Survey (ATMI) (Tapia, 1996). Qualitative data about the experimental group including levels of
engagement and the effectiveness of instructional design of the software utilized were also gathered.

Positive outcomes of the study include making “best practices” recommendations for remedial mathematics instruction of math-delayed middle school students. Data accumulated in the study contributes to the body of evidence on the usefulness of technology-based remediation practices and provides important information to school officials in the development of curricular and budgetary decisions.
CHAPTER ONE
INTRODUCTION

Foundations of the Study

With educational reform measures prevalent in school systems nationwide due to the No Child Left Behind Act (NCLB) of 2002, curriculum decisions are increasingly made based on empirical evidence of the efficacy of proposed educational programs as federal funding will go only to those initiatives that are backed by such evidence (United States Department of Education, 2007a). This need for Evidence Based Education (EBE) has emphasized the lack of “gold standard” studies in the area of mathematics education due to the quality of the research required to meet such rigorous standards of research (United States Department of Education, 2007b). According to the 2007 National Assessment of Education Progress (NAEP), the average math scores of fourth and eighth graders have improved; however, only thirty percent of eighth graders nationwide are proficient in math. The need for additional research on mathematics pedagogical practices is further emphasized by the 2000 National Center for Education Statistics report on Remedial Education at Degree-Granting Postsecondary Institutions that states that thirty-five percent of all entering freshman are enrolled in remedial math courses and that these numbers are considered to be unacceptably high (Merisotis & Phipps, 2000). Computation capabilities of American students appear to be falling. After responses to select items on the NAEP, it was concluded that performance on basic arithmetic facts declined in the 1990’s. Clearly, students need help to develop rapid, effortless, and errorless recall of basic math facts (Loveless, 2003).

The focus of this research project is to examine the efficacy of middle school mathematics multimedia-based Computer Assisted Instruction (CAI) through an evidence-based lens. Evidence Based Education is defined as the integration of professional wisdom with the best available empirical evidence in making decisions about how we deliver education – “what
works, with what children, under what circumstances” (Whitehurst, 2002). The What Works Clearinghouse created by the United States Department of Education accepts both experimental and quasi-experimental studies to review, giving greater weight to the experimental rather than the quasi-experimental (United States Department of Education, 2007b). The mathematics education literature relating to CAI reveals a disparity among academic achievement results ranging from significantly positive to significantly negative effect sizes (Slavin, Lake, & Groff, 2007).

Although randomized trials are considered the “gold standard” in scientific-based research, quasi-experimental evidence is often accepted as it is understood that randomization rarely occurs in the real world (United States Department of Education, 2007b). Scientific-based research involves the application of rigorous, systematic, and objective procedures to obtain reliable and valid knowledge relevant to education activities and programs (Redfield, 2003). Observational or quasi-experimental non-equivalent control group studies take advantage of naturally occurring events that lend themselves to accurate data recording. Quasi-experimental research is generally considered acceptable when the control and experimental groups have been closely matched by determining the same achievement levels at the onset of the treatment or if statistical measures are used to compensate for pre-existing differences among the groups (“Learning Point Associates”, 2007).

Technology Usage and Learning Outcomes

A long standing debate in the educational technology literature is whether media or pedagogy makes technology-mediated learning more or less effective. Clark (1983) stated that the best current evidence is that media are mere vehicles that deliver instruction, but do not influence student achievement any more than the truck that delivers groceries causes changes in our nutrition. Kozma (1991) countered by suggesting that capabilities of a particular medium, in
conjunction with methods that take advantage of these capabilities, interact with and influence the ways learners represent and process information and may result in more or different learning when one medium is compared to another for certain learners and tasks.

Clark (1983) based his theory on media studies from the decades preceding this statement in which he admits that in effect size analyses, a small positive effect for newer media over more conventional instructional delivery devices was found. Kulik, Kulik, and Cohen’s (1980) meta-analysis cited studies that explained the phenomena in which the positive effect for media more of less disappears when the same instructor produces all treatments. In this meta-analysis definite advantages to the use of media such as time saving features and cost effectiveness of computers were examined, but emphasis was placed on the possible novelty effect with new media which results in heightened student interest as a confounding variable in that the increased attention paid by students sometimes results in increased effort or persistence, which yields achievement gains, but that these gains diminish as students become more familiar with the new medium (Clark, 1983).

Kozma (1991) separates learning with books, television, computers, and multimedia by distinguishing types of media by their symbol systems, technologies, and processing capabilities and the learning theories associated with the medium. Kozma points out that some students will learn a particular task regardless of the delivery device while others will take advantage of a particular medium’s characteristics to help construct knowledge. For example, the process of learning with computers is influenced by the ability of the medium to dynamically represent formal constructs and instantiate procedural relationships under the learner’s control which are used by some learners to construct, structure, and modify mental models (Kozma, 1991). Taking into account for different learning styles of students, Kozma states that other students with prior knowledge and processes might find the use of computers unnecessary, but has encouraged
continued research by stating that our ability to take advantage of the power of emerging technologies will depend on the creativity of designers, their ability to exploit the capabilities of the media, and our understanding of the relationship between these capabilities and learning.

Kozma (1994) has pointed out that media capabilities have changed considerably since the time of the studies reviewed by Clark (1983) and that they will change more in the near future. These developing capabilities may, in turn, change the ways in which designers interact with media and enable more powerful designs which emerge from this interaction. The question we should now ask is, “In what ways can we use the capabilities of media to influence learning for particular students, tasks, and situations?” (Kozma, 1994).

Cobb (1997) elaborates on Kozma’s ideas by stating:

“The notion that external stimuli, representations, symbol systems, and media are peripheral to cognition, and therefore to learning, is an idea attached to a body of cognitive theory that has now been substantially modified. There is still no fully elaborated learning theory from which a media theory would follow, but there are nonetheless some points where media research can be usefully aligned with recent cognitive research.”

Clark (1994), sounding more flexible in his views than in the previous decade, states that there is strong evidence that many very different media attributes accomplish the same learning goal. There is no single media attribute that serves a unique cognitive effect for some learning tasks and the attributes must be proxies for some other variables that are instrumental learning gains. Clark (1994) insists on a replacability test:

“Whenever you have found a medium or set of media attributes which you believe will cause learning for some learners on a given task, ask yourself if another similar set of attributes would lead to the same learning result. If you suspect that there may be an alternative set or mix of media that would give similar results, ask yourself what is causing these similar results.”

Cobb (1997) advised a three point approach which addresses many of the issues brought to light in the media debate. Media do have a great deal to do with learning and it is generally recognized that the ability to interface with symbolic media and integrate their outputs is nearer
the heart of human cognition than the periphery. It is up to the media specialist to determine which medium will best accommodate targeted learners utilizing the same level of efficiency – whether economic, logistic, social, or cognitive. Researchers also utilize empirical studies and not just qualitative measures in determining the validity of utilizing media for instructional purposes. Used properly, technology can lead to gains in academic achievement and positively influence the social environment of the school, reducing teacher and student absenteeism and increasing morale (Wenglinsky, 1998).

Theoretical Perspective

According to the National Center for Technology Innovation (NCTI) Mathematics Matrix, there are six purposes of technology usage for supporting students mathematical learning, including

“(1) building computational fluency, (2) converting symbols, notations and text, (3) building conceptual understanding; (4) making calculations and creating mathematical representations; (5) organizing ideas, and (6) building problem solving and reasoning.”

These six purposes support the development of students’ declarative, procedural, and conceptual knowledge (Hasselbring, Lott, & Zydney, 2005).

In this study, two CAI programs are examined for their effect on student academic achievement, spatial visualization, and attitudes toward mathematics. While the primary focus of this study is to measure the academic effectiveness of the software utilized in the Sharpening Math Skills Lab (pseudonym), quantitative and qualitative data collected on spatial visualization, student attitudes toward mathematics, and student perceptions of the effectiveness of the principles of instructional design will provide explanatory information.

The inclusion of spatial visualization data in the study is based on the theoretical perspective linking it to an individual’s general mathematical problem solving ability (Kaufman, 1985; Fischbein, 1987; Bishop, 1989; Brown & Wheatley, 1989, 1997; Wheatley, 1991;
Zimmerman, 1991; Battista, 1994). Measuring student attitudes toward mathematics is based on studies that identify math-delayed students as lacking in motivation due to low levels of self-efficacy in mathematics which has led to history of poor performance in the subject area (Covington, 1992; Middleton & Spanias, 1999; Dweck, 2000; & Kroesbergen, 2002).

Software implementation of Moreno and Mayer’s (2000) principles of instructional design are also examined make connections to student learning. These include the split-attention principle, the spatial contiguity principle, the temporal contiguity principle, the modality principle, the redundancy principle, and the coherence principle. These six principles illustrate multimedia interfaces that allow students to work easily with verbal and non-verbal representations of complex systems. They are developed based on numerous studies conducted by Mayer and his colleagues.

The six principles of instructional design introduced have important theoretical implications. According to a generative theory of multimedia learning (Mayer, 1997),

“active learning occurs when a learner engages three cognitive processes – selecting relevant words for verbal processing and selecting relevant images for visual processing, organizing words into a coherent verbal model and organizing images into a coherent visual model, integrating corresponding components of the verbal and visual models.”

Statement of the Problem

While the NCLB Act of 2002 calls for educational agencies to make use of scientifically-based research in curriculum decision making processes, there are a limited number of studies available to educators to provide guidance in the area of mathematics, especially in the area of multimedia mathematics instruction (U. S. Dept. of Education, 2007b). Many published studies are the direct result of research initiatives by the developers of interactive multimedia software who publish only the results that will encourage school systems to purchase their products.

Numerous studies have determined small, but positive effects of technology-based pedagogical practices on learning outcomes in mathematics CAI. Conversely, other studies have
yielded significantly positive and significantly negative effect sizes which indicate a need for further study. These studies need to be further analyzed for details of program administration which may provide explanations for the effect size results. In addition to measuring the effects of learning outcomes, examining the characteristics of learners and their interactions with the specific design attributes of technology-mediated programs such as those that support Moreno and Mayer’s (2000) six principles of multimedia instructional design may yield guidelines for successful implementation of mathematics CAI.

Purpose of the Study

The purpose of this study is to compare the effects of the interactive multimedia mathematics instructional programs utilized in the Sharpening Math Skills Lab project: Tom Snyder Publications FASTTMath and Houghton Mifflin Larson Intermediate Mathematics iSucceed with regular mathematics instruction of middle school students in two other middle schools in the same district. In addition to comparing the academic achievement of the experimental and control groups, learner interactions with specific content-delivery media attributes will be examined to determine a relationship between the spatial visualization ability of math-delayed students and their ability to problem solve. Information on the attitudes, perceptions, and levels of engagement of students who participate in the Sharpening Math Skills Lab will also be explored to determine if these learning experiences provide increased motivation for student achievement.

The types of mathematics instruction are the independent variables and the dependent variable will be the standardized mathematics achievement results of Scantron Achievement Series Mathematics Test. The experimental group will consist of a convenience sample of approximately 109 sixth, seventh, and eighth grade students participating in the Sharpening Math Skills Lab project at Middle School One. The control group will consist of a convenience
sample of 113 math-delayed students from Middle School Two and 49 math-delayed students from Middle School Three who receive regular mathematics instruction using the Louisiana Comprehensive Curriculum and Glencoe Mathematics textbook.

Research Questions

1. Do students who scored in the Unsatisfactory or Approaching Basic levels on the iLEAP (Spring 2007) who participate in the Sharpening Math Skills Lab using FASTTMath and iSucceed interactive multimedia mathematics instructional activities make greater gains on the Scantron Mathematics Tests than other low-performing students who do not participate in the program?

2. Will participation in the Sharpening Math Skills Lab using FASTTMath and iSucceed interactive multimedia mathematics instructional activities increase the spatial visualization ability of students as demonstrated by performance on a pre and post test of Wheatley’s Spatial Ability Test?

3. Is there a correlation between math-delayed student problem solving ability and their spatial visualization ability?

4. What are the specific multimedia principles of instructional design implemented in the software program interfaces in the Sharpening Math Skills Lab and what are the student perceptions of the effectiveness of the software program features?

5. What are the attitudes and classroom behaviors of math-delayed students who participate in the Sharpening Math Skills Lab concerning mathematics learning experiences?
Significance of the Study

This research advances the study of specific cognitive theories and attributes of media which will be examined as well as the efficacy of multimedia-based CAI for mathematics. Although some studies of technology-mediated mathematics programs have revealed both significantly positive and significantly negative effect sizes, best evidence synthesis (Slavin & Lake, 2006) and meta-analysis (Slavin, Lake, & Groff, 2007) of mathematics CAI programs have indicated small, positive median effect sizes. While it can be reasonably expected that this study will reveal a small positive effect size on student academic achievement, the greatest significance of the study will be narrowing the focus to qualify the actual results through the examination of the specific theoretical perspectives that contribute to the quality of learner interactions with technology-mediated content such as the learner’s spatial visualization ability (Wheatley, 1991; Moreno & Mayer, 2000), attitudes toward mathematics, perceptions of effectiveness of multimedia design principles, and levels of student engagement (Tapia, 1996).

This study will provide educators with additional resources to improve remedial learning environments for math-delayed students by making connections between learner interactions and specific attributes of media, especially those that relate to spatial visualization. Research has indicated that a student’s spatial visualization ability is directly related to their ability to problem solve in mathematics. Math-delayed students are generally acknowledged to have a low level of spatial visualization ability (Wheatley, 1991). This study will provide information on whether the specific media attributes of the programs utilized in the Sharpening Math Skills Lab improve student spatial visualization ability and if this results in improved student mathematical problem solving ability. Positive outcomes of the study include making “best practices” recommendations for remedial mathematics instruction of math-delayed middle school students.
Data accumulated in the survey will add to the body of evidence on the usefulness of technology-based remediation practices which will result in important implications to the participating organizations in the Sharpening Math Skills Lab project. Study findings will provide important curricular and budgetary information to local school officials as to the replacability of the Sharpening Math Skills Lab project in other low-performing schools and to the company and consulting firm responsible for the implementation of the initial project. Currently in the first year of a three-year grant, the Sharpening Math Skills Lab in Middle School One was funded by the international parent corporation of a national company with a local manufacturing facility. The parent corporation uses a national educational consulting firm which works closely with local school agencies to oversee the implementation of all their educational grants. This study will provide invaluable information to the collaborating organizations which will guide future decision making and help to shape the next two years of the Sharpening Math Skills Lab project in Middle School One.

Definition of Terms

Automaticity – Performance of any cognitive skill automatically; automated procedures requiring very few cognitive resources.

Cognitive load theory – A theory proposed by John Sweller and his associates focusing on working memory’s role in instructional design.

Computer Assisted Instruction (CAI) – technology-mediated activities designed for drill-and-practice, tutorial, or simulation activities offered either by themselves or as supplements to traditional, teacher-directed instruction.

Interactive - refers to media activities that allow for frequent participation or responses by the user.
Math facts – refers to the memorization of basic math operations: addition, subtraction, multiplication, and division of numbers 0 -12.

Math-delayed – refers to students who are experiencing a disruption in the normal development of their network of relationships between mathematical facts and answers.

Multimedia - media that uses multiple forms of information content and information processing (e.g. text, audio, graphics, animation, video, or interactivity) to inform or entertain the (user) audience.
CHAPTER TWO

REVIEW OF THE LITERATURE

Introduction

The purpose of this study is to determine if the Sharpening Math Skills Lab technology-mediated mathematics instructional practices for math-delayed middle school students have positive effects on their mathematics achievement, spatial visualization ability, engagement in learning, perceptions of effectiveness of multimedia design principles, and attitudes toward mathematics instruction. This chapter will review the relevant literature for each facet of the study: computer guided instruction, the principles of instructional design emphasizing spatial visualization, computer assisted mathematics instruction, and the characteristics of math-delayed students.

Computer Guided Instruction

The purposes for which technology are applied in education have been categorized as learning “from” computers and learning “with” computers (Reeves, 1998). Learning “with” technology is a constructivist approach to using multi-media as tools to help students develop higher order thinking, creativity, and research skills. When students are learning “from” computers, the computers are essentially tutors. Learning “from” computers is often referred to as computer assisted instruction (CAI), computer-based instruction (CBI), Integrated Learning Systems (ILS), and intelligent learning systems (ITS). In these capacities, the technology primarily serves the goal of increasing the student’s basic knowledge and skills (Ringstaff & Kelly, 2002). The software utilized in the Sharpening Math Skills Lab fall into the category of computer-assisted instruction.

Computer tutoring programs are sometimes considered to be synonymous with computer-assisted instruction (CAI) as they present instructional materials to a learner, require the learner
to respond to the material, evaluate the response, and then on the basis of the evaluation
determine what to present next (Kulik, 2003). Computer tutoring programs are meant to do the
same things that individual tutors do, but these machines can store vast amounts of instructional
material and present it with sophisticated graphics, animations, and audio help.

Research studies that examine the impact of technology-mediated skill enhancement
programs reveal mixed results (Wilson, 1993; Butzin, 2000). A number of studies suggest that
these programs increase students’ basic skills in mathematics (Koedinger, Anderson, Hadley, &
Mark, 1997). Other studies report that in some instances, the use of computers to teach basic
skills had a negative impact on academic achievement (Wenglinsky, 1998; McKenzie, 1999).
Still others argue that many of the studies comparing CBI, CAI, and ILS with traditional
instruction are so methodologically flawed that no conclusions can be drawn (Ringstaff & Kelly,
2002).

In 1994 Kulik aggregated findings from over 500 individual studies of computer-based
instruction. Of the studies conducted prior to 1990, effect sizes ranging from +0.22 to +0.57
were reported for computer-based applications of different levels for different applications. In
this meta-analysis Kulik divided computer learning tasks into seven categories and reported their
respective achievement effect sizes: Tutoring (58 studies, ES=+0.38), Managing (10 studies,
ES=+0.14), Simulation (6 studies, ES=+0.10), Enrichment (5 studies, ES=+0.14), Programming
(9 studies, ES=+0.09), and Logo (9 studies, ES=+0.58). Most noteworthy from Kulik’s (1994)
meta-analysis is that students usually learned more in classes that included computer tutoring.
Offering details of the tutoring category, Kulik (2003) states,

“results of the 58 studies of computer tutoring were favorable to technology-based
teaching approaches. In 55 of the 58 studies, the test scores of the computer tutorial
group were higher than the control group’s scores; in the remaining studies, the control
group’s scores were higher. The effect sizes in the 58 studies were between -0.42 and
+1.44. The median effect size was +0.36. This effect is large enough to be considered
educationally meaningful. It suggests that computer-tutored students would perform at
the 64th percentile on relevant achievement tests, whereas conventionally taught students would perform at the 50th percentile.”

Table 2.1 illustrates the results of the more recent studies from the Kulik (2003) meta-analysis, both student achievement and student attitudes were examined with positive effects noted for each. In five out of the six studies of achievement effects, the computer-tutorial group outscored the control by an amount that was large enough to considered both statistically significant and educationally meaningful (Kulik, 2003).

Adonri and Gittman’s investigation (1998) resulted in large effects on both achievement and attitudinal outcomes. The researchers studied a tenth grade global studies course in a public high school in Brooklyn, New York. Experimental and control groups were chosen by random selection and assignment with a pretest confirming the equivalence of the two groups. The experimental group received CAI in a computer laboratory for 40 minutes a day for two days per week for six weeks and the control group received traditional instruction. The achievement posttest results indicated an effect size of +1.48. An attitude survey also showed a statistically significant increase in interest in the subject for students in the experimental group (ES=+3.09).

Bain, Houghton, Sah, and Carroll (1992) found large tutorial effects on both achievement and attitude measures. The investigators studied the effects of an interactive video program used to teach social problem solving to grade seven classes in Perth, Australia. Students were randomly assigned to three groups: an experimental group (N=13) received interactive video instruction only; a second group (N=14) received teacher-led instruction with linear video; a third group (N=13) received teacher led instruction with no video support. After six lessons a criterion-referenced achievement test and attitude survey were administered. The interactive video condition proved superior to the control group in achievement (ES=0.76) and in attitudes toward instruction (ES=1.10).
Table 2.1 Computer Guided Instruction Meta-analysis Results

<table>
<thead>
<tr>
<th>Study</th>
<th>Subject</th>
<th>Sample Size</th>
<th>Effect Size</th>
<th>Achievement</th>
<th>Attitudes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adonri &amp; Gittman (1998)</td>
<td>Social Studies</td>
<td>70</td>
<td>1.48*</td>
<td>3.09*</td>
<td></td>
</tr>
<tr>
<td>Bain, Houghton, Sah, &amp; Caroll (1982)</td>
<td>Social problem solving</td>
<td>40</td>
<td>0.76*</td>
<td>1.10*</td>
<td></td>
</tr>
<tr>
<td>Gardner, Simmons, &amp; Simpson (1993)</td>
<td>Weather</td>
<td>93</td>
<td>1.06*</td>
<td>0.43</td>
<td></td>
</tr>
<tr>
<td>Jegede, Okebukola, &amp; Ajewole (1991)</td>
<td>Biology</td>
<td>64</td>
<td>-0.01</td>
<td>3.71*</td>
<td></td>
</tr>
<tr>
<td>Lazarowitz &amp; Huppert (1993)</td>
<td>Biology</td>
<td>181</td>
<td>0.42</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Yalcinalp, Geben, &amp; Ozkan (1995)</td>
<td>Chemistry</td>
<td>101</td>
<td>0.42</td>
<td>0.33</td>
<td></td>
</tr>
</tbody>
</table>

Note: * Indicates statistically significant values.
The data represented in this table was created by the author of this study from information presented in the Kulik (2003) meta-analysis.

Gardner, Simmons, and Simpson’s investigation (1993) also found very large tutoring effects on student achievement. The experimental and control groups of third graders in Atlanta Georgia participated in 10 days of hands-on meteorology activities with the experimental group also working in the CAI program Weatherschool. Analyses revealed an effect size of 1.06 on the meteorology test and 0.43 on attitudes toward science and computers.

Yalcinalp, Geben, and Ozkan (1995) found moderate effects of tutoring effects among secondary school students in Ankara, Turkey. Randomly assigning students to two classes of general science, the experimental group received two hours per week for four weeks of researcher-developed tutorial program on mole-number-mass interrelations in elements and compounds. Control group students received traditional instruction during the same period. The experimental group outscored the control group on both achievement (ES=0.42) and attitude scales (0.33).
Lazarowitz and Huppert (1993) found moderate effect sizes in a high school biology class in Israel. In this four week study, the researchers assigned the experimental group to a combination of classroom laboratory instruction and the CAI software program, The Growth Curve of Microorganisms, a researcher-developed program. The control group students received laboratory instruction only. Analysis of covariance was used to adjust for differences in the groups and effect size was 0.42.

Jegede, Okebukola, and Ajewole (1991) found no computer tutoring effect on student achievement. In a study of high school students in Nigeria, students were randomly assigned to three groups: 10 students used the tutorial program School Software BIO 101 individually for three months, 30 students used the program in groups of three, and 24 control students received conventional instruction. The results of an achievement test on relevant topics were effect size – 0.01 and an attitude questionnaire were effect size -3.71.

Overall the results of these six studies suggest that computer tutoring can be very effective aid when it is used in teaching concepts in elementary and secondary schools (Kulik, 2003). The median effect size for these studies was 0.59 for the achievement measures which suggests that students who received computer tutorial instruction would perform at the 72nd percentile on their tests, whereas students receiving conventional instruction alone would perform at the 50th percentile. For attitudinal measures, the effect size was 1.10 which indicates that students have favorable attitudes toward instruction and the subject being taught using CAI.

Computer Assisted Mathematics Instruction

In a meta-analysis of 39 studies of various forms of computer assisted learning (CAI) in middle and high school mathematics median Effect Size (=+0.16) was reported (Slavin, Lake, & Groff, 2007). This modest impact is very similar to the median of +0.19 reported by Slavin and Lake (2006) for elementary applications of CAI. Studies included in the Slavin, Lake, and Groff
(2007) meta-analysis of middle and high school mathematics CAI programs and the Slavin and Lake (2006) best-evidence synthesis of elementary mathematics CAI programs met the minimum requirements of randomized or matched control group, study duration of at least twelve weeks, and equality at pretest.

In a quantitative synthesis of achievement outcomes of elementary mathematics CAI programs shown in Table 2.2, Slavin and Lake (2006) included 38 qualifying studies of which 15 used random assignments. While some of the studies included in this synthesis are programs that are no longer commercially available, the CAI implemented in the majority of these studies were a supplement to instruction in which the programs were rarely used more than three 30 minute sessions per week. In all cases, control groups used non-technology approaches, such as traditional textbooks which is similar in approach to the control groups in this study which are using textbooks and the Louisiana Comprehensive Curriculum.

In analysis of program subscales in Josten’s Compass Learning, CCC/Successmaker, and other CAI, computational skills revealed greater academic outcomes than concepts or problem solving. This information is useful in predicting outcomes for the experimental group’s use of Tom Snyder Productions FASTTMath which is a supplemental program used for 10 minutes daily, but not for the Larson Intermediate iSucceed Mathematics program as it is a core CAI program designed for real world context problem solving and is used thirty to forty minutes five days per week.

Table 2.3 features the programs that Slavin, Lake, and Groff (2007) categorize in their middle and high school meta-analysis: Core CAI in which the computer largely replaces the teacher, Supplemental CAI which is defined as one in which students work on computers for 10 – 15 minutes each day to improve math skills, providing core instruction, opportunities
Table 2.2  Best-evidence Synthesis Results of Computer Assisted Elementary Mathematics Instruction

<table>
<thead>
<tr>
<th>Program Name</th>
<th>No. of Studies</th>
<th>Median Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAI</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Josten's Compass Learning</td>
<td>7</td>
<td>+0.24</td>
</tr>
<tr>
<td>CCC/Successmaker</td>
<td>5</td>
<td>+0.17</td>
</tr>
<tr>
<td>Lightspan</td>
<td>1</td>
<td>+0.28</td>
</tr>
<tr>
<td>Classworks</td>
<td>2</td>
<td>+0.56</td>
</tr>
<tr>
<td>Other CAI</td>
<td>18</td>
<td>+0.25</td>
</tr>
<tr>
<td><strong>Computer-managed Learning Systems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accelerated Math</td>
<td>5</td>
<td>+0.12</td>
</tr>
</tbody>
</table>

Note: The data represented in this table was created by the author of this study from information presented in the Slavin & Lake (2006) synthesis.

Table 2.3  Meta-analysis Results of Computer Assisted Middle and High School Mathematics Instruction

<table>
<thead>
<tr>
<th>Program Name</th>
<th>No. of Studies</th>
<th>Median Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Core CAI</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive Tutor</td>
<td>7</td>
<td>+0.12</td>
</tr>
<tr>
<td>I Can Learn</td>
<td>8</td>
<td>+0.14</td>
</tr>
<tr>
<td>Learning Logic Lab</td>
<td>1</td>
<td>-0.78*</td>
</tr>
<tr>
<td>The Expert Mathematician</td>
<td>1</td>
<td>+0.38</td>
</tr>
<tr>
<td><strong>Supplemental CAI</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jostens/Compass Learning</td>
<td>1</td>
<td>+0.22</td>
</tr>
<tr>
<td>PLATO</td>
<td>2</td>
<td>+0.25</td>
</tr>
<tr>
<td>SRA</td>
<td>1</td>
<td>+0.38</td>
</tr>
<tr>
<td>Other</td>
<td>13</td>
<td>+0.31</td>
</tr>
<tr>
<td><strong>Computer-managed Learning Systems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accelerated Math</td>
<td>5</td>
<td>+0.07</td>
</tr>
</tbody>
</table>

Note: * Indicates statistically significant values.
The data represented in this table was created by the author of this study from information presented in the Slavin, Lake, & Groff (2007) meta-analysis.
for practice, assessment, and prescription, and Computer-managed Learning Systems CAI in which a computer is used to assess students, print out individualized assignments, score the assignments, and provide feedback to teachers on student progress for use in regular instructional practices. While most of the effect sizes among the 39 studies were small to moderate, one study stands out with a statistically significant negative effect size.

The mean effect sizes from the studies included in Slavin and Lake’s (2006) best evidence synthesis of elementary mathematics CAI and Slavin, Lake, and Groff’s (2007) meta-analysis of middle and high school mathematics CAI are similar. The middle and high school results are explored in greater depth in this literature review because of the outliers in the study effect sizes and the relevance to this study. An in depth examination of several of the middle and high school studies has relevance to this literature review as the programs used in the Sharpening Math Skills Lab, FASTTMath and iSucceed have features of all three categories of CAI. Tom Snyder Productions FASTTMath is a Supplemental program in which students work ten minutes each day to improve their fluency with basic mathematical operations. The Larson Intermediate Math’s iSucceed program may largely be classified as a Core CAI program. The iSucceed program is web-based and computer adaptive as students are pretested for each learning module and lessons are presented according to identified areas of student need. The iSucceed program also has several features of a Computer-managed Learning Systems CAI such as individualized assessment and print-out student assignments.

Core CAI Studies

Selected studies of Core CAI including Cognitive Tutor, I Can Learn (ICL), Learning Logic Lab, and The Expert Mathematician programs are included in this section. In Core CAI technology-mediated activities, the teacher’s role is to circulate among the students, provide encouragement, and answer questions, but not to provide extensive direct instruction (Slavin,
Lake, & Groff, 2007). Available details of the instructional design principles are included with each program.

Cognitive Tutor

Seven studies of Cognitive Tutor, a core CAI program were conducted, two of which were quasi-experimental and the remaining five were matched quasi-experimental studies. Across the seven studies of the core CAI program, Cognitive Tutor, the median effect size was +0.12. Two randomized quasi-experiments by Cabalo & Vu (2007) and Morgan & Ritter (2002) had a median effect size of +0.17 (Slavin, Lake, & Groff, 2007). The five matched quasi-experimental studies resulted in a median effect size of +0.12.

Cognitive Tutor programs are based on the ACT-R theory of learning and performance (Anderson & Lebiere, 1998) which distinguishes between procedural knowledge and declarative knowledge and empirical studies of learners to create a cognitive model (Koedinger, 2002). Cognitive Tutor was analyzed by Koedinger (2002) utilizing four instructional bridging design principles: Situation Abstraction in which a bridge from concrete situational to abstract symbolic representations is made, Action-Generalization in which a bridge from doing with instances to explaining with generalizations, Visual-Verbal in which pictures and verbal/symbolic representations are integrated, and Conceptual-Procedural in which conceptual and procedural instruction is integrated. The critique of the Visual-Verbal principle is relevant as it relates to the Moreno and Mayer (2000) principles of instructional design. The Visual-Verbal bridging design principle recommends instruction that helps students integrate visual, spatial, or analog representations of an idea with verbal, sequential, or digital representations of that idea. In Cognitive Tutor Algebra, the use of multiple representations of functions, the more visual graph and table representations and the verbal symbolic situation and equation representations, is
consistent with this principle, but was not found to be generally or explicitly applied in all applications of the software (Koedinger, 2002).

In the Cabalo and Vu (2007) quasi-experimental study of Cognitive Tutor, 541 students in 22 classes from grades eight through thirteen were assessed after a year of program participation yielded a small effect size of +0.03. Classes were randomly assigned within teachers by a coin-flip, so each teacher taught both experimental and control classes which link to Clark’s (1983) idea that the positive effect for media more or less disappears when the same instructor produces all treatments. Effect size did vary by subtest, with the control group scoring significantly higher than the Cognitive Tutor group in two of the mathematical strands, Quadratic Equations (ES = -0.33, p<.01) and Algebraic Operations (ES = -0.25, p<.01) which may point to specific design features of those design modules as being particularly beneficial.

In the Smith (2001) matched study of the CAI program, Cognitive Tutor, the subjects were similar in academic achievement to the students in the Sharpening Math Skills Lab. Cognitive Tutor was evaluated in seven urban high schools in Virginia. Subjects were low-achieving students who completed a three-semester course in pre-algebra. Outcome variables included the students’ scores on the Virginia Standards of Learning (SOL) Algebra I test. Covariates were the SAT-9 pretest scores. The control group used a traditional textbook program. Although students were assigned classes with a computerized scheduling program, equivalence was not assured. Experimental and control group classes were well matched on the SAT-9. Attrition was a contributing factor in the study, but similar in the experimental and control groups. Analysis of covariance found no difference between the experimental and control groups, with students in the control group scoring slightly better than those taught with Cognitive Tutor after adjustment for pretests (ES= -0.07).
I Can Learn

The results of eight studies of the core CAI Program, I Can Learn resulted in a median of +0.14. An acronym for Interactive Computer-Aided Natural Learning, I Can Learn was found by the What Works Clearinghouse to have a positive effect on academic achievement (United States Department of Education, 2007c). The multi-media features of the I Can Learn pre-algebra and algebra lessons include instructional videos and interactive multimedia presentations. Connecting math topics to real world applications lessons are groups much those in a traditional textbook. While progressing through the lesson, students receive verbal and visual assistance. After completing a lesson, students complete a cumulative review of the concepts taught and teachers can monitor student progress through real-time achievement (United Stated Department of Education, 2007c).

Learning Logic Lab

The Learning Logic Lab (LLL) study (McKenzie, 1999) produced significantly negative results with a finding of a negative effect size of -0.78. Learning Logic Lab is a self-paced mastery learning CAI program used as a core approach to mathematics (Slavin, Lake, & Groff, 2007). Features of Learning Logic Lab include customization features, progress reports, and computerized test generation and homework. Graphic resources include an online gradebook, glossary, calculator, curvalator, formulator, and graphalator. In the Learning Logic Lab study McKenzie (1999) evaluated the academic performances of four classes in a southern Georgia high school. Two classes using Learning Logic Lab for Algebra I instruction were compared to two traditional-methods mathematics classes. Pretest means favored the control group, but controlling for these differences with analyses of covariance, the control group gained substantially more than the treatment group (ES= -0.78, p<.001).
The Expert Mathematician

The Expert Mathematician is a middle school program that uses LOGO programming language to progress students through a constructivist, integrated series of computer and workbook activities emphasizing problem solving and creativity. In this matched, quasi-experimental study, Baker (2005) assigned an experimental group of 90 eighth grade students to use the software and a control group receiving traditional math instruction. Using analysis of covariance to adjust for pretest differences between the groups, posttest results indicate an effect size of +0.38. Although a non-significant difference, it noteworthy because it is larger than the majority of the studies included in the Slavin, Lake, and Groff (2007) meta-analysis.

Supplementary CAI Studies

The supplementary computer assisted programs evaluated had a median effect size of +0.29. Programs included in the Slavin, Lake, and Groff (2007) meta-analysis include Jostens/Compass Learning, Plato Web Learning Network and Science Research Associates (SRA) Drill and Practice. A widely used and evaluated supplementary CAI programs was originally called Jostens, and is now called Compass Learning. Like all integrated learning system (ILS) programs, Jostens/Compass Learning provides an extensive set of assessments, which places students according to their current levels of performance and then gives students exercises designed primarily to fill in gaps in their skills (Slavin, Lake, & Groff, 2007). ILS programs are typically used for a short portion of the instructional class period, 15 to 30 minutes per day and may be used 2 - 3 days per week. These models provide teachers with regular reports of student progress similar to the FASTTMath program used in the Sharpening Math Skills Lab.
Accelerated Math

Accelerated Math is a technology-mediated assessment and instructional management system. It was the only computer-managed learning system evaluated in the Slavin, Lake, and Groff (2007) meta-analysis. In the five included studies a median effect size of +0.07 was found. Students take a computer-adaptive test, and based on the results, the computer assigns practice exercises appropriate for the students’ current level of achievement. Activities in Accelerated Math are pencil and paper, with computer generated and readable answer sheets. After completing an exercise, students feed their answer sheet through a scanner which is connected to a computer and a report of the results is presented. Accelerated Math is not a typical CAI program, in that the computer is used only for assessment, prescription, and scoring. However, the program is very similar to a CAI program in that it provides supplemental, individualized practice and feedback to students and teachers (Slavin, Lake, & Groff, 2007).

Learner Interactions with Multimedia

Cognitive Load Theory

To understand the principles of instructional design as they relate to multimedia CAI, it is important to understand how the human mind processes information and stores this information in memory. The Cognitive Load Theory (CLT) assumes that some working environments impose a greater demand than others and therefore demand a higher processing load on limited cognitive resources in working memory (Sweller, et al, 1998). The Cognitive Load Theory suggests that learning happens best under conditions that are aligned with human cognitive architecture which is a combination of memory and schemas (Kirschener, 2002). In simpler terms, short-term or working memory (STM or WM) is what the reader is using at this very moment to process this text (stimuli have entered the sensory register through attention and
recognition). It is used for all conscious activities and it is the only memory that can be monitored. Content and function are concealed in this process until brought into working memory.

Learners are limited to about seven items or elements of information at any one time in working memory (Bruning, Schraw, Norby, & Ronning, 2004). Furthermore, because working memory is also used to organize, contrast, compare or work on that information, only two or three items of information can be processed simultaneously as opposed to merely holding that information. Finally, working memory is seen not as one monolithic structure, but rather a system embodying at least two mode-specific components: a visual-spatial sketchpad and a phonological loop coordinated by a central executive (Yu, 2002).

Long-term memory (LTM) is, in contrast, used to make sense of and give meaning to what activities an individual engaging in at any given moment. It is the repository for more permanent knowledge and skills and includes all things in memory that are not currently being used but which are needed to understand (Bower, 1975). Most cognitive scientists believe that the storage capacity of LTM is unlimited and that is a permanent record of everything that an individual has learned. Although an individual is never conscious of LTM, awareness of its contents and functioning is filtered through working (conscious) memory.

Schema are stored in long term memory and schemata categorize information elements according to how they will be used (Chi, Claser, & Rees, 1982). Comprising large quantities of information, a schema is processed as a single unit in working memory. When schemata integrates information elements and production rules, automated processes result requiring less storage and controlled processing.
Principles of Instructional Design

Moreno and Mayer’s (2000) cognitive theory of multimedia learning, illustrated in Figure 2.1, explains the process by which information presented in a multimedia format is transferred to sensory memory, working memory, and long-term memory. The principles of instructional design provide multimedia explanations that allow students to work easily with verbal and non-verbal representations of complex systems: the split-attention principle, the spatial contiguity principle, the temporal contiguity principle, the modality principle, the redundancy principle, and the coherence principle (Moreno & Mayer, 2000).

Figure 2.1 Depiction of A Cognitive Theory of Multimedia Learning

Principle One: The Split Attention Principle

The split-attention principle illustrated in Figure 2.2 demonstrates that multimedia programs utilizing both animation and narration enable students to store information in visual working memory and represent the corresponding narration in auditory working memory.

Mayer and Moreno’s (1998) study addressed improved student learning when verbal information is presented auditorily as speech rather than visually as on-screen text. The outcome of this experiment showed that students who learn with concurrent narration and animations outperform those who learn with concurrent on-screen text and animations. Concurrent multimedia presentations force the text groups to hold material from one source of information
(verbal or non-verbal) in working memory before attending to the other source. In a dual-coding theory (Paivio, 1971), one stimulus composes both a linguistic system and an imagery system providing two distinct memory traces. The two systems are independent, yet interconnected in that an individual has the capability of translating non-verbal information into verbal and verbal into non-verbal information. The connection of verbal and visual representations during the meaning-making process provides a rationale for the use of multiple visual representations in instructional practices. If students learn a concept with several different representations, connections between them are made to improve mental schemes, which results in better learning.

For Group AN, the incoming animation and narration initially are held in different working memory spaces.

Principle Two: The Modality Principle

The concept that students learn better when the verbal information is presented auditorily as speech rather than visually as on-screen text both for concurrent and sequential presentations comprises the modality principle (Moreno & Mayer, 2000). In a study of the modality principle Moreno and Mayer examined the performance of three groups of college students. One group viewed concurrently on-screen text while viewing the animation, a second group listened
concurrently to a narration while viewing the animation, a third group listened to a narration preceding the corresponding portion of the animation, a fourth group listened to the narration following the animation, a fifth group read the on-screen text preceding the animation, and the sixth group read the on-screen text following the animation. The modality effect is evidenced by the text groups as they scored significantly lower than the narration groups in problem solving transfer. There was no significant difference between each modality group in their performance for transfer. The results of this study are similar to findings with prior studies on text and diagrams (Mousavi, Low, & Sweller, 1995).

**Principle Three: The Redundancy Principle**

In a study of the redundancy principle (Moreno & Mayer, 2000) which describes the presentation of visual materials such as animations, video, or graphics with simultaneous text and audio, a significant interaction between redundancy and presentation order was found. Consistent with the predictions of a dual-processing theory of multimedia learning, students presented with redundant verbal materials outperformed students who learned with non-redundant verbal materials when the presentations were sequential. The opposite was discovered to be true for simultaneous presentations of animations and explanations which is attributed to a split-attention effect between the on-screen text and the animation. The redundant message hurts rather than helps students’ learning.

**Principle Four: The Spatial-contiguity Effect**

In a review of ten studies concerning whether multimedia instruction is effective, Mayer (1997) concluded that there was consistent evidence for a spatial-contiguity effect. Students were shown to have generated a median of over 50% more creative solutions to transfer problems when verbal and visual explanations were integrated than when they were separated. The conclusion that students learn better when on-screen text and visual material are physically
integrated rather than separated was validated through additional multimedia studies in learning environments where the verbal and visual explanations were in close physical proximity of the onscreen text and the animation was manipulated, the onscreen text was separated or physically far from the animation, or the animations and narration were concurrent. Of specific relevance to this study is the Mayer and Sims (1994) study which revealed that the contiguity effect is strong for high spatial ability students, but not for low spatial ability students. An additional study of the split attention principle (Moreno & Mayer, 1998) showed that students who learn with concurrent narration and animations outperform those who learn with concurrent on-screen text and animations.

Principle Five: The Temporal-contiguity Principle

According to the temporal contiguity principle, students learn better when verbal and visual materials are temporarily synchronized rather than separated in time. Congruent to a dual-procession model of working memory, meaningful learning is fostered when the learner is able to hold a visual representation in visual working memory and a corresponding verbal representation in verbal working memory at the same time (Moreno & Mayer, 2000). The results of this study indicate that animation should be presented in chunks depicting only a short sequence as to not overload working memory.

Principle Six: The Coherence Principle

In a test of the coherence principle, it was determined that students learn better when extraneous material such as music is excluded rather than included in multimedia explanations (Moreno & Mayer, 2000). Adding relevant and coordinated auditory material in the form of environmental sounds did not hurt student learning, but an auditory overload created by music or additional sound effects resulted in fewer cognitive resources being allocated to building connections among words, images, and sounds.
Principles of Instructional Design in Multimedia Mathematics

The principles of instructional design examined in this study relate specifically to multimedia interface between the material and the user. For communication from the program to the user, this is primarily the computer screen and how it is designed, but it can also include sound or other forms of output (Alessi & Trollip, 2001). In a study of teaching in a multimedia computer learning environment (Chuang, 1999) on learning style, gender, and math achievement the presentation effects of text, oral narration, and computer animation were examined. Four versions of the same courseware were developed to study the interface effects of animation and text, animation and voice, animation, text, and voice, and free choice in which the students could select their interface effects. Study results indicated that subjects performed significantly better on the posttest in the animation, text, and voice version, which was also the most commonly selected interface design among the free choice subjects. The study also found that the animation, text, and voice interface effect was only strong for those subjects with the field independence learning style, males, or students with low math achievement.

These results are of significance as it conflicts with findings in Moreno and Mayer’s (1998) Split Attention Principle study of non verbal information presented auditorily as speech rather than visually as on-screen text. The outcome of the Moreno and Mayer investigation which is used to validate the Split Attention Principle showed that students who learn with concurrent narration and animations outperform those who learn with concurrent on-screen text and animations.

Spatial Visualization

Mathematical visualization and imagery (Zimmerman, 1991) is the process of forming images (mentally, or with pencil and paper, or with the aid of technology) and using such images effectively for mathematical discovery and understanding. Wheatley (1991) defines mental
imagery as constructing an image from pictures, words or thoughts; re-presenting the image as needed; and transforming that image. Kaufman (1985) further states that imagery has its most important function in the initial phase of the problem solving process. Love (1995) suggests that the relationship between mental objects and physical images is an especially difficult one.

Is there a link between being good at spatial problems and general problem-solving skills? The idea that imagery aids creative problem solving in unfamiliar problems, is supported by Kaufman (1985),

“It may now be argued that the location of verbal and visual symbolic representation on the two dimensions of ‘level of processing’ and ‘type of processing’ may be seen to point in the same direction in relation to the novelty parameter in problem solving. Linguistic representation is the more appropriate and economical the higher the degree of task familiarity. With increasing situational novelty, the functional significance of visual imager will increase.”

Brown and Wheatley (1989, 1997) report that students who achieved above average scores on standard mathematics test but who had low spatial ability were poor at problem solving. Wheatley (1991) states,

“students with high spatial ability whose performance was average or below on standardized mathematics tests and in school mathematics class had an excellent grasp of mathematical ideas and were able to solve non-routine problems, often creatively.”

The relationship between spatial ability and mathematical ability is based upon the fact that operations performed while interacting with mental models in mathematics are often the same as those used to operate in spatial environments (Battista, 1994). A visual image not only organizes the data at hand in meaningful structures, but is also an important factor guiding the analytical development of a solution (Fischbein, 1987). There is value in emphasizing visual representation in all aspects of the mathematics classroom (Bishop, 1989).

A verbal link is evident as learners become proficient at manipulating mental models they may begin to use words as ‘pointers’ to important operations and to think without additional presentation of the operations.
Battista (1994) illustrates this point by stating,

“familiar problems might be solved by referring to verbally encoded propositions or procedures, by-passing the spatial like thinking required to use the underlying mental model. Even though such thinking may appear strictly verbal, for it to be conceptually meaningful and powerful enough to encompass novel situations, it must be based – at some level – on operations with mental models.”

In a study of the effects of mathematics instruction utilizing an electronic whiteboard at the Florida State University School in Tallahassee, Florida, Robinson (2004) administered Grayson Wheatley’s Wheatley Spatial Ability Test (WSAT) Form B (Appendix A). The instrument was used to measure students’ gains in spatial visualization skills as a result of the use of the interactive electronic whiteboard during a six day mathematics unit of study on transformations. Student visualization performance increased in both the control and experimental classes. In a T-test for difference in means, no significant difference was found and the null hypothesis, which stated that the mean visualization gains of the control and experimental classes are statistically equal is not rejected.

Treatment Software Programs

FASTTMath

FASTTMath uses the Fluency and Automaticity through Systematic Teaching with Technology (FASTT), based on nearly two decades of research on the development of mathematical fluency in math-delayed and non-math-delayed children. The principles of FASTTMath have been validated over several years of research with more than 400 students. In a quasi-experimental matched study by Hasselbring and Goin (2005), three groups of students were matched for age, sex, and race. Two of the groups consisted of math-delayed students and the remaining group consisted of non-math-delayed students. The experimental group of math-delayed students received 54 10-minute sessions on the software program for addition. The other two groups, the non-math delayed and the math-delayed contrast group received only
traditional fluency instruction delivered by the classroom teachers. Test results were not reported by effect size; however, on average the experimental group gained 19 new fluent facts while their math-delayed peers receiving traditional instruction gained no new facts and their non-math delayed peers gained only seven new facts. The maintenance data gathered four months after the post-test following summer vacation indicated that students regressed only 6 facts. According to Hasselbring, Goin, and Bransford (1988) once facts become fluent through this method, they are retained at a high level. The positive results of this experiment have been replicated several times across all four mathematical operations. Although FASTTMath is effective for all students needing assistance with developing fact fluency, it appears to be especially effective for students labeled as at-risk and learning disabled.

FASTTMath is based on the rationale that human beings have a limited capacity for information processing. Cognitive psychologists have discovered that humans have fixed limits on attention and memory used to solve problems. One way around these limits is to have certain components of a task become so routine and over-learned that they become automatic (Whitehurst, 2003). Automatic cognitive processes or automaticity require fewer resources than non-automated processes, therefore learners need fewer resources to perform tasks where their skills are automated than those tasks requiring conscious attention and thought. It is generally agreed that automatic processes require little or no attention for their execution and are acquired only through extended practice (Bruning, Schraw, Norby, & Ronning, 2004).

Automaticity in mathematics creates a fluent retrieval that is needed for the development of higher-order mathematics skills – such as multiple-digit addition and subtraction, long division, and fractions (Resnick, 1983). Studies have found that a lack of math fact retrieval can impede participation in math class discussions (Woodward & Baxter, 1997). The term math facts refer to the automaticity of basic math operations: addition, subtraction, multiplication, and
division of numbers 0 -12. Also affected are successful mathematics problem solving (Pellegrino & Goldman, 1987) and the development of everyday life skills (Loveless, 2003). Rapid math fact retrieval has been shown to be a strong predictor of higher-level functioning and performance on mathematics achievement tests (LaBerge & Samuels, 1974; Lesgold, 1983; Torgensen, 1984; Royer, Tronsky, Chan, Jackson, & Marchant, 1999).

If a student constantly has to compute the answers to basic facts, less of that student’s thinking capacity can be devoted to higher-level concepts than a student who can effortlessly recall the answers to basic facts (Hasselbring & Goin, 2005). Recent research in cognitive science using functional Magnetic Resonance Imaging (fMRI) has revealed the actual shift in brain activation patterns as untrained math facts are learned (Delazer et al, 2003). As predicted by Dehaene and fellow researchers (2003), instruction and practice cause math fact processing to move from a quantitative area of the brain to one related to automatic retrieval. According to Delazer and her colleagues (2003),

“this shift aids the solving of complex computations that require “the selection of an appropriate resolution algorithm, retrieval of intermediate results, storage and updating in working memory by substituting some of the intermediate steps with automatic retrieval.”

Mathematical knowledge of basic facts is classified as declarative knowledge and procedural knowledge. Declarative knowledge or factual knowledge is basically knowing that something is the case (Smith & Ragan, 1999) and can also be conceptualized as an interrelated network of relationships containing basic problems and their answers (Bruning et al, 2004). Procedural knowledge refers to methods that can be used to derive answers for problems lacking pre-stored answers. Students with learning problems have not established a declarative knowledge network and instead of retrieving facts from memory, rely on procedural knowledge. Underlying both declarative and procedural knowledge in mathematics is a type of understanding

“number sense as the ability to naturally decompose numbers, use particular numbers as referents, solve problems using the relationships among operations and knowledge about the base-ten system, estimate a reasonable result for a problem, and have a disposition to make sense of numbers, problems, and results. For example, children in the lower elementary grades can learn that numbers can be decomposed and thought about in many different ways--that 24 is 2 tens and 4 ones and also two sets of 12.”

According to Garnett (1992) all elements – number sense, procedural knowledge, and declarative knowledge must be developed together to achieve full math fact fluency.

Note. Reprinted with permission from Tom Snyder Productions (Hasselbring & Goin, 2005)

Figure 2.3 Presenting Non-fluent Facts Interspersed With Previously Mastered Facts

To develop fluency in math-delayed children, a mental link between the facts and answers has to be established (Hasselbring & Goin, 2005). According to the FASTTMath software developers, this is accomplished through the identification of fluent and non-fluent information, restricted presentation of non-fluent information, student generation of
problem/answer pairs, used of controlled response times, spaced presentation of non-fluent information, and appropriate use of drill and practice. FASTTMath develops a declarative knowledge network by interspersing the two new “target” facts with other already automatized facts in a pre-specified, expanding order which is illustrated in Figure 2.3. Each time the target fact is presented, another automatized fact is added as a “spacer” so that the amount of time between presentations of the target fact is expanded. The expanding recall model requires the student to retrieve the correct answers to the target facts over longer and longer periods.

Larson Intermediate iSucceed Math

Larson Learning Intermediate iSucceed Math program is described as a data-driven math intervention solution for students who have not yet mastered the fundamentals (Butler & Good, 2004). Considered to be an innovative system combining technology powered by Larson Learning® and print, this multimedia, multi-sensory program incorporates the best practices of teacher-directed group instruction, interactive courseware, active practice with games, fact fluency, and one-on-one tutoring.

The developers of Larson Learning Math Courseware conducted research which was designed and implemented by their team using Larson’s Intermediate Math with fourth grade students to investigate the effectiveness and impact of the program on student learning. The data were collected and sent to the Institute for the Advancement of Research in Education (IARE) at the Appalachian Regional Education Laboratory (AEL) in Charleston, West Virginia for analysis. The primary research question posed in the study was “Did students with access to Larson’s Intermediate Math perform better on mandated mathematics tests than students without access to the program?”

This non-randomized quasi-experimental study was implemented at Sunflower Elementary School in Paola, Kansas and Trojan Elementary Schools in Osawatomie, Kansas.
Sunflower Elementary, as the experimental group, assigned one hundred one fourth grade students to receive regular classroom instruction supplemented by Larson’s Intermediate Math approximately three times per week in a computer laboratory setting throughout the school year. Fourth graders at Trojan Elementary Schools were chosen to be the control group. One hundred three students received regular classroom instruction with no access to Larson’s Intermediate Math. The California Achievement Test, Fifth Edition (CAT/5) in the fall and spring was used as the measurement instrument. The IARE study confirmed that the difference in the performance between the experimental and control groups on the Fall CAT/5 was statistically insignificant. The spring CAT/5 test scores revealed statistically significant differences between the control groups and the experimental groups. While effect size was not reported, the spring test scores show differences between the two groups that range for 6.86 to 9.65 in each of the three test measurements: computation, concepts and applications, and total mathematics (Butler & Good, 2004).

In additional studies on Larson Intermediate Math in California Schools, the percent of second graders in Ramona Elementary School in Alhambra, California during the 2000 – 2001 school year scoring at or above the 50th National Percentile (NPR) in mathematics on the STAR Stanford 9 Test increased by nineteen percent compared to a state-wide increase of one percent. Cottonwood Creek Elementary purchased Larson’s Intermediate Math for grades 3 through 6 in August 1999. From 1999 to 2002, the percent of fifth grade students of Cottonwood Creek Elementary, Englewood, Colorado ranking as Proficient or Advanced in mathematics increased by 17.7% compared to a state-wide increase of 8%.

Charlotte County School District’s Liberty Elementary in Port Charlotte, FL implemented Larson Intermediate math throughout the school and reported an increase on their FCAT mathematics scores from 2001 to 2003 by 21 points compared to a state-wide gain of 6
points. In the Miami-Dade County School District fourth grade students of Miami Heights Elementary increased their FACT mathematics scores by 18 points compared to a state-wide increase of 4 points which they attribute to the use of Larson Intermediate software.

During the 2001 – 2002 school year, in New York’s Community School District 31 fourth graders in several Staten Island schools were evaluated for their use of Larson Intermediate Math. At public School 13 Margaret Lindemeyer School the number of fourth grade students of who met or exceeded the standards in mathematics increased 5.3% compared to a state-wide decrease of 1%. Other schools in the district, Public School 14 Cornelius Vanderbilt School reported an increase of 12.4% compared to a state-wide decrease of 1%. Public School 22 Graniteville School mathematics standards scores increased 3.6% compared to a state-wide decrease of 1%. Public School 29 Bardwell School had a 6.4 % increase in mathematics scores compared to the 1% decrease.

In the Scranton, Pennsylvania School District at John Adams Elementary School Number Four, the number of students scoring proficient or advanced increased by 54.1% compared to a statewide increase of 3.2% on the Pennsylvania System of School Assessment (PSSA) during the 2002 to 2003 school year after implementing Larson Intermediate Math in the school.

Additional reports of Larson Intermediate Math success stories are reported from Texas schools. From 1999 to 2003, the number of third grade students of Corrigan-Camden Independent School District passing the TAKS Test in mathematics increased by 24.3% compared to a state-wide increase of 7.7%. Fourth grade TAKS Test scores in mathematics increased by 25% compared to a state-wide increase of 0.4%. At Houston Independent School District’s Raul C. Martinez Elementary from 2001 to 2003, the number of third grade students passing the TAKS Test in mathematics increased by 28.8% compared to a state-wide increase of
7.7%. The number of third graders at North Euless Elementary in Euless, Texas increased TAKS Test scores by 11.2% compared to a state-wide increase of 7.7%.

Characteristics of Math-Delayed Students

The subjects in this research study are students encountering difficulties with learning mathematics, which also encompasses some children with learning disabilities who receive special education services and children performing below average without a specific disability who attend regular education classes. The students in the experimental and control groups will be referred to as math-delayed students and defined as students performing in the Approaching Basic or Unsatisfactory levels on the Integrated Louisiana Educational Assessment Program test (iLEAP) which is Louisiana’s state criterion and norm-referenced mandated test.

Although the students in the study have difficulty with mathematics, many of them have other difficulties as well. It is also possible that difficulties with reading, language and writing may negatively influence the students’ math performance (Mercer, 1997). Despite this diversity, it is nevertheless possible to present some general characteristics of students who have difficulties learning math (Kroesbergen, 2002).

Math-delayed students often have difficulties learning due to memory deficits (Rivera, 1997) and particularly problems with the storage of information in long-term memory and the retrieval of such information (Geary, Brown, & Samaranayake, 1991). These same students demonstrate greater difficulties than their peers with the automatized mastery of such basic skills and often have to calculate the answers that others know directly (Pellegrino & Goldman, 1987). Deficits in this area can influence students’ later math performance and their mastery of the remainder of the math curriculum (Kroesbergen, 2002).

According to Kroesbergen (2002), another characteristic of math-delayed students is their inadequate use of strategies to compute answers or solve word-problems. This may be partially
explained by their memory deficits which produce slower development of the relevant strategies than in normal achieving students (Rivera, 1997). Inadequate strategy use may be caused by metacognitive deficits (Goldman, 1989) which are necessary for the identification, selection, and application or appropriate problem-solving strategies (Kroesbergen, 2002).

Another characteristic of math-delayed students is deficits in other metacognitive regulation processes such as the organization, monitoring, and evaluation of information (Mercer, 1997). As a result of these deficits, the students often produce mistakes showing the incorrect application of solutions. These students often feel they have completed the problem correctly and are unaware that they need to attempt to evaluate the procedures they apply as good problem solvers (Kroesbergen, 2002). Math-delayed students have difficulties with connecting different tasks and with the application of already acquired knowledge and skills to new or different tasks (Goldman, 1989).

In addition to memory and metacognitive deficits, math delayed students may also have attention deficits and motivational problems (Kroesbergen, 2002). Middleton and Spanias’ (1999) synthesis of research on motivation in mathematics suggests that when a student fails repeatedly in math, he or she tends to attribute that failure to a stable belief. Taking an attributional stance, the student sees their poor performance as a function of low ability instead of other attributes such as the difficulty level of the task or the amount of effort put forth by the student (Dweck, 2000). After several years of often frustrating experiences, students develop a low level of self-efficacy and tend to avoid academic challenges, often by adopting self-handicapping strategies for coping with failure (Covington, 1992). Low achieving students in general become less involved in schoolwork over time.

Helping math-delayed students develop the belief that it is possible for them to succeed in mathematics is a complicated issue. Offering students a series of relatively easy tasks can lead to
a false sense of self-efficacy, and this practice is at odds with the intent to give students access to challenging mathematics (Kroesbergen, 2002). Research indicates that achieving a balance between sufficient opportunities for success and tasks that require considerable effort requires carefully designed curricular materials and instructional practices (Woodward, 1999).

Research shows that low achieving students with and without learning disabilities achieve significantly lower and therefore sustain a higher rate of failure experiences that non-labeled low achieving students (Donohoe & Zigmond, 1990; Kavale, Fuchs, & Scruggs, 1994; Merrill, 1990; Shinn, Ysseldyke, Deno, & Tindal, 1986), engender more controlling responses from parents and teachers and are more likely to suffer from the phenomenon of learned helplessness (Deci & Chandler, 1986).

While the subjects of this study are comprised of both special and regular education students, a central tenet of the National Council of Teachers of Mathematics (NCTM) Standards (1989, 2000) has been that all students can succeed in complex mathematics. Known as the equity principle, the NCTM advocates that all children should have access to a coherent, challenging mathematics curriculum.

In a multiple-measure study to examine the task-related behavioral differences between learning disabled and low-achieving students in mainstream classes and teacher ratings of low-frequency problem behaviors, 18 learning disabled students and 18 low achieving students from three high schools were compared to identify differences (Bender, 1985). Study results indicate that the learning disabled group was found to demonstrate significantly less on-task behavior than the low-achieving group, $F(2.34) = 3.86; p < .05$, across settings. The learning disabled group was on-task approximately 79% of the time compared with 85% for the low-achieving group. Neither setting nor interaction proved significant for on-task behavior.
In a study to examine the effects of a curriculum designed to specifically address the characteristics of math-delayed middle school students at risk for special education in mathematics, 53 students in two middle schools located in medium-sized, suburban school district were the subjects. The experimental group received an intervention of a curricular approach based on principles identified in the special education literature.

Researchers measured achievement levels using McGraw-Hill CBT Terra Nova and gauged attitudes and beliefs about mathematics of both experimental and control groups. Study results indicate non-significant differences between groups, $F(1,51) = 1.55, p = .22$, but significant differences for the amount of time participating in math $F(1,51) = 35.60, p < .001$, as well as significant interactions for groups and time participating in math, $F(1,51) = 8.58, p = .01$. Due to the significant interaction, $t$ tests were performed on the pretest and posttests. There were non-significant differences between groups on the pretest, $t(1,51) = 1.29, p = .21$, but significant differences between groups on the posttest $t(1,51) = 2.35, p < .05, d = 1.23$, favoring the intervention students. Cohen’s $d$ indicates relatively large effect sizes for posttesting indicating that student attitudes were positively influenced by the intervention.

A forty item survey entitled “Attitudes Toward Math Inventory” to assess general attitudes toward the subject and the extent to which students thought they (a) were good at problem solving, (b) worked well with numbers, and (c) believed that working hard in mathematics led to doing well in the subject. This pretest and posttest measure was group-administered and provided a global indication of student attitudes toward math. A 2 x 2 ANCOVA was performed on the “Attitudes Toward Math Inventory” measure using the pretest CTB Terra Nova score as the covariate in this analysis. Results indicate significant differences between groups $F(1,50) = 11.46, p = .001$, and time, $F(1,50) = 178.01, p < .001$, as well as significant interactions for groups and time, $F (1,50) = 267.42, p < .001$. These results are
encouraging in that they reflect the need to modulate instructional activities so that students have frequent opportunities for success and other occasions when problems cannot be solved immediately or even individually (Kroesbergen, 2002).

Paired or small-group instruction in which teachers scaffold understanding and assist in the completion of the task, can be an effective way of increasing student motivation (Kroesbergen, 2002). Researchers have also suggested that students need occasional opportunities in which they are not immediately successful on tasks so they develop a more reasonable sense of self-efficacy (Middleton & Spanias, 1999).

Summary and Implications for the Study

The literature review reported numerous studies meeting quality criteria on the effects of academic achievement for both computer guided instruction in a variety of subjects and mathematics CAI. The results of meta-analyses of quality studies of both computer guided instruction (Kulik, 2003) and specific mathematics CAI software applications (Slavin, Lake, & Groff, 2007) report low positive median effect sizes for both middle and high school low-achieving students and students of average and above average ability. In some cases these median effect sizes are the result of outliers of significantly positive (Gaeddert, 2001) and significantly negative effect sizes (Wenglinsky, 1998; McKenzie, 1999), indicating a disparity in findings. A variety of school settings, student demographics, and student achievement levels were represented in these studies; however, more information on how the programs were administered and the specific CAI features is needed to provide a complete picture of why these programs may or may not have been successful in terms of statistically significant student achievement gains.

Based on the research findings of the three types of CAI identified by Slavin, Lake, and Groff (2007), Supplemental, Core, and Computer-managed Learning Systems, which have
similar features of the programs used in the Sharpening Math Skills Lab, it can be reasonably expected that the low-achieving students in Middle School One using both FASTTMath and iSucceed will demonstrate academic growth in mathematics. While this research indicates that under certain circumstances CAI in mathematics is beneficial to student academic achievement, the computer guided instructional programs reviewed for the purposes of this study are missing specific information that relate to the multimedia principles of instructional design. Many of the featured programs have not been evaluated or critiqued for implementation of research-based instructional design features such as those developed by Moreno and Mayer (2000).

The literature also reports mixed results on the idea that the specific learning problems of math-delayed students such as a difficulty in math fact retention, low spatial visualization ability, and lower levels of student engagement may be addressed through remedial CAI mathematics programs. This presents a two-fold need for further investigation relating to the effects of multimedia design features such as the split-attention principle, the spatial contiguity principle, the temporal contiguity principle, the modality principle, the redundancy principle, and the coherence principle (Moreno & Mayer, 2000) on math-delayed students. The first identified need is to learn more about the effects of specific multimedia features present in CAI mathematics programs on low-achieving student attitudes, motivation, and levels of student engagement in a technology-mediated mathematics learning environment geared to individual student performance levels. The second is to establish the relationship between spatial visualization and student mathematical ability in these students and then to determine if learner-content interaction utilizing these features improves student spatial visualization ability.

In conclusion, the literature review reveals that further examination of the principles of multimedia instructional design (Moreno & Mayer, 2000) as they relate to the programs such as those utilized in the Sharpening Math Skills Lab, the relationship between student spatial
visualization (Wheatley, 1991), student attitudes and motivation toward mathematics (Tapia & Marsh, 2004), and student behavior as they engage in multimedia learning activities is warranted.
CHAPTER THREE
METHODOLOGY

Introduction

The purpose of this study is to determine if the Sharpening Math Skills Lab technology-mediated mathematics instructional practices for math-delayed middle school students has positive effects on their mathematics achievement, spatial visualization ability, engagement in learning, and attitudes toward mathematics instruction. This chapter describes the research questions, participants, and research methods that will be used in the study, Multimedia Mathematics Intervention for Math-Delayed Middle School Students.

Research Questions

1. Do students who scored in the Unsatisfactory or Approaching Basic levels on the iLEAP (Spring 2007) who participate in the Sharpening Math Skills Lab using FASTTMath and iSucceed interactive multimedia mathematics instructional activities make greater gains on the Scantron Mathematics Tests than other low-performing students who do not participate in the program?

2. Will participation in the Sharpening Math Skills Lab using FASTTMath and iSucceed interactive multimedia mathematics instructional activities increase the spatial visualization ability of students as demonstrated by performance on a pre and post test of Wheatley’s Spatial Ability Test?

3. Is there a correlation between math-delayed student problem solving ability and their spatial visualization ability?

4. What are the specific multimedia principles of instructional design implemented in the software program interfaces in the Sharpening Math Skills Lab and what are the student perceptions of the effectiveness of these features?
5. What are the attitudes, perceptions, and classroom behaviors of math-delayed students who participate in the Sharpening Math Skills Lab concerning mathematics learning experiences?

Study Setting

At a Southwest Louisiana middle school, sixth, seventh, and eighth students who scored in the Unsatisfactory or Approaching Basic levels in mathematics on the mandated standardized achievement iLEAP test receive forty-five minutes per day of instruction in the Sharpening Math Skills Lab (pseudonym). Since this is the only program of its kind in the state of Louisiana, a pseudonym is used in this study to protect the identity of the students. These students also receive forty-five minutes per day of regular mathematics instruction using the Louisiana Comprehensive Curriculum and Glencoe Mathematics Textbook series for their specific grade level. Students will be using Tom Snyder Publications FASTTMath, Houghton Mifflin Larson Intermediate Mathematics iSucceed while receiving coaching from their grade-level mathematics teacher and the lab facilitator in the Sharpening Math Skills Lab. Data on student achievement will be collected through the administration of both the Performance Series and Achievement Series Scantron Mathematics tests, the Wheatley Spatial Ability Test (WSAT) and survey instruments to gauge student perceptions and attitudes on participating in a multimedia mathematics instructional program.

Study Program Implementation

The Sharpening Math Skills Lab Project at Middle School One is a collaborative venture between a major United States manufacturing corporation, a national educational consulting firm, and a southwest Louisiana school district. Corporate grant funds were used to purchase 30 multimedia computers with Internet access and software. The local school system provides the project facilitator. The project is designed to help math-delayed students in grades 6, 7, and 8
improve academic achievement in mathematics by pinpointing their current level of performance and designing an individualized technology-mediated curriculum for each student. Students also receive coaching from the project facilitator and their math teachers to achieve a level of proficiency where they can succeed in their regular classes.

Students were selected to participate in the Sharpening Math Skills Lab based on Spring 2007 iLEAP scores of Approaching Basic or Unsatisfactory. Using the Larson Intermediate iSucceed math software, the project facilitator designed a curriculum for each student based on the results of their August 2007 Scantron Performance series scores. This was accomplished by including components of each mathematics strand learning module according to the Louisiana State Department of Education Grade Level Expectation (GLEs). Learning modules that did not specifically address GLEs were excluded from the curriculum. The project facilitator then matched student performance level indicators from the Scantron Performance series test with the appropriate GLEs for each student. For example, a student scoring at the third grade level on the Scantron Performance series test would be assigned a modified third grade Larson iSucceed curriculum. These modified curricula were assigned the names of football teams, so that students would not be aware that they were being placed in programs that are several grades lower than their actual grade placement.

Each day the six classes (two per grade level) of math-delayed students enter the lab with their math teacher and begin with ten minutes of supplemental math instruction using server-based FASTTMath software. From there students log-in to Larson’s iSucceed web-based software where they work at their own pace through the interactive learning modules for approximately half an hour. Students must demonstrate mastery of each learning module with at least an 80 percent correct score before being allowed to move on to the next learning module. When a student has successfully completed all of the modules for a particular grade level, a new
Software Programs Principles of Instructional Design Evaluation

As one of the purposes of this study is to determine the effectiveness of the software used in the Sharpening Math Skills Lab the principles of instructional design used in the development of the software interfaces first need to be identified. To accomplish this task, the multimedia interfaces of the two software programs, Tom Snyder Productions FASTTMath and Larson Intermediate iSucceed software, were evaluated by the researcher using the Principles of Instructional Design Observation Protocol (PIDOP).

The PIDOP, based on the research of Moreno and Mayer (2000), contains twelve indicators of design features which are keyed to the six principles of instructional design: split attention principle, modality principle, redundancy principle, temporal principle, coherence principle, and the spatial contiguity principle. Over a period of 8 weeks the researcher recorded data on the characteristics of the multimedia interface design as learners interacted with the FASTTMath and iSucceed software. The participant observer recorded each time a specific design feature is observed as students use the program software. Field notes were also recorded on the observation protocol forms. The results are reported in the following narrative.

FASTTMath Evaluation Results

FASTTMath is accessed through the local school system’s network server which enables students and teachers to access data from any machine in the lab. Students are verbally coached through an auditory interface and provided with an update on the Fact Tracker screen (Figure 3.1) where each individual is presented with a grid displaying which math facts they have mastered for a given operation.
In this phase of the FASTTMath program, verbal information is presented both auditorily and as text concurrently with onscreen graphics (PIDOP Indicator 11). By definition, this negates the effects of the Redundancy Principle which states that students learn better from animation and narration than from animation, narration, and text if the visual information is presented simultaneously to the verbal information (Moreno & Mayer, 2000); however, the only function of this screen is to provide the student with information on their current level of performance.

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Figure 3.1 FASTTMath Student Fact Tracker

Proceeding to the Study Facts See It! Screen (Figure 3.2), students are presented with a review of the next math facts they are to master. Selecting the See It! icon provides the student with an animated representation of the math fact in which narration and text are presented concurrently (PIDOP Indicator 11) and are physically integrated (PIDOP Indicator 4) illustrating the redundancy principle, the spatial contiguity principle, and the coherence principle (Moreno & Mayer, 2000).
The spatial contiguity principle (Moreno & Mayer, 2000) is illustrated in both Figure 3.1 and Figure 3.2 as text is physically integrated or close to the onscreen graphics in this part of the program (PIDOP Indicator 4).

From there the program moves into an interactive automaticity fact drill where students type in a response when the fact appears on the screen. Student responses to the auditory cue or sound effect can be seen in the form of smiles or grimaces depending on whether they get a chirpy “beep” of approval for a correct response or a low pitched “bonk” for an incorrect response. The presence of this extraneous material conflicts with the Coherence Principle (Moreno & Mayer, 2000) which states that students learn better when extraneous material is excluded rather than included in multimedia explanations. Students are also auditorily coached to “say the fact out loud to yourself and then re-type it” (PIDOP Indicator 7) when an incorrect response is given which exemplifies both the redundancy principle and the modality principle (Moreno & Mayer, 2000). The modality principle states that students learn better when the verbal information is presented auditorily as speech rather than visually as on-screen text both for concurrent and sequential presentations.
Scores for the math fact automaticity (Figure 3.3) measures both correct answers and the speed in which the answers were generated. On this screen, text and animation are presented asynchronously (PIDOP Indicator 2) which conflicts with the split attention principle (Moreno & Mayer, 2000); however, the information presented is merely to inform, not to teach.

![Image of FASTTMath Fact Tracker Study Facts Scores](image)

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Figure 3.3 FASTTMath Fact Tracker Study Facts Scores

If students do well on their math fact automaticity drills, the software provides them with the opportunity to visit the Style Gallery to make selections to their screen design features. As a new row of facts is “unlocked” (see Figure 3.1), more features are added to the Style Gallery. After mastering at least 70 facts, students also have the option of selecting from six drill and practice games. Figures 3.4 and 3.5 are screen shots of two of these games which were evaluated and compared using the PIDOP. In both Electraball (Figure 3.4) and Helicopter Hogs (Figure 3.5) onscreen animations are physically integrated close to onscreen animations (PIDOP Indicators 1 and 4) which illustrate the spatial contiguity principle (Moreno & Mayer, 2000).
The split attention principle is in effect as the math facts are only presented as text instead of text and narration. The temporal contiguity principle (PIDOP Indicators 6 and 10) is efficiently utilized as the verbal and visual materials are temporarily synchronized in time. The coherence principle (PIDOP Indicator 12) is contradicted throughout the reinforcement games with extraneous background sound effects and correct or incorrect auditory feedback. For example, when a student correctly answers a question in Electraball, a loud zapping sound accompanies the animated lightning. In the Helicopter Hogs game, the helicopter rotors are heard continuously as well as the squealing of the hogs in response to student input. This adaptive program moves the learner into either an exercise in increasing math fact automaticity (Figure 3.2), a fact reinforcing video game (Figures 3.4 and 3.5), or a reward visit to the style gallery where they can customize their screen with color and graphic design options.
The principles of instructional design (Moreno & Mayer, 2000) strengths of FASTTMath include spatial contiguity and temporal contiguity which were consistently observed when the software was in use. The redundancy and split attention principles were incorrectly applied in informational formats such as Fact Tracker Math Facts and Score screens, but were effectively applied in See It! and the drill and practice screens. For the most part, the modality principle was consistently applied. The weakest principle of the six was the coherence principle due to the presence of extraneous sound effects throughout the program.

Larson iSucceed Evaluation Results

Larson Intermediate iSucceed Math encompasses approximately twenty mathematical strands ranging from basic operations with whole numbers to integers and algebra for students on the third through sixth grade levels. Sharpening Math Skills Lab students are working in individually designed curricula which use selected components from many strands. When students log-in to iSucceed, the opening screen (Figure 3.6) lists all of the individualized math modules with pre-test and lesson status. Progress is sequential and access to subsequent modules
is blocked until a student has demonstrated a mastery level of at least 80 percent in their current module.

![Figure 3.6 Larson iSucceed Student Main Menu](image)

**Note:** Reprinted with permission from Houghton Mifflin Harcourt Publishing Company

**Figure 3.6 Larson iSucceed Student Main Menu**

The iSucceed program starts the learning sequence for each module with a tutorial lesson, then moves into problem solving exercises. Lesson assessment is in the form of a short, timed Zap It! quiz, a Master Challenge test, and a Standardized Test. Although there are a variety of components in the lesson modules, the screen presentation format is universally applied. This section will report on the evaluation of the principles of a set of problem solving exercises.

The sequence of problem solving using Venn Diagramming is illustrated in Figure 3.7 and Figure 3.8. When a lesson or problem solving screen is presented, the directions are always given auditorily (PIDOP Indicator 7), but may or may not be presented as text (PIDOP Indicators 1, 11). When the direction text is not present, the split attention, redundancy, and modality principles are evidenced as student attention is not divided between multiple sources of mutually referring information, the visual information is presented simultaneously to the verbal
information, and verbal information is presented auditorily as speech for concurrent and sequential presentations (Moreno & Mayer, 2000).

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Figure 3.7 Larson iSucceed Problem Solving Screen One

The temporal contiguity principle is evidenced by the synchronization of the visual and verbal materials (PIDOP Indicators 6, 10). An artificial asynchronous condition may be created because students have the option to have the directions repeated or listen to the problem by selecting the appropriate button on the bottom left of the screen, but the onscreen graphics and text do not change while the narration is repeated.

The onscreen text is physically integrated or close to onscreen graphics (PIDOP Indicator 4), illustrating the spatial contiguity principle (Moreno & Mayer, 2000). The only observed incidence of verbal information presented as text following onscreen graphics (PIDOP Indicator 3) is seen when feedback is given in the form of “That’s Correct! Good Work!” which is
illustrated in Figure 3.8. Since that text is not instructional in nature, it is discounted in the
evaluation of the spatial contiguity principles. No auditory or visually extraneous material was
observed in the iSucceed software, reinforcing the coherence principle (Moreno & Mayer, 2000).

The web-based Larson iSucceed software demonstrated strength in several of the
principles of instructional design. The spatial contiguity, temporal contiguity, and coherence
principles were consistently demonstrated throughout the lesson, problem solving, and
assessment components of the program. As measured by the definitions of the principles of
instructional design, the presentation of verbal information as both text and as narration connote
weaknesses in the split attention, modality, and redundancy principles. They are inconsistently
applied in the Larson iSucceed software as illustrated in Figure 3.9. Although narration was
always presented with each screen with opportunity for repetition, text was not always present.

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Figure 3.8 Larson iSucceed Problem Solving Screen Two
Participants

Participants include 171 math-delayed middle school students from grades six, seven, and eight from three southwest Louisiana middle schools. The demographics of these schools are displayed in Table 3.1. For the purpose of this study, math-delayed students are defined as students performing in the Approaching Basic or Unsatisfactory levels on the Integrated Louisiana Educational Assessment Program test (iLEAP) which is Louisiana’s state criterion and norm-referenced mandated test. In addition to selecting the control and experimental groups based on their iLEAP scores, groups were matched for their socio-economic levels indicated by individual school Title One status. A school is eligible for Title One when over half of the student population is eligible for free or reduced price lunches. Local school officials have
indicated that Middle School One would qualify for Title One status, but the application process has not been completed.

Experimental Group

The 109 math-delayed students in the experimental group are comprised of a convenience sample scheduled for participation in the CAI Sharpening Math Skills Lab at Middle School One in a school district in southwest Louisiana. The demographics of the experimental group are illustrated in Table 3.2. Due to scheduling conflicts and a limited number of computers, only a portion of the math-delayed students at Middle School One were scheduled for the lab. The remaining math-delayed students in the school were not participants in the study.

Table 3.1 Experimental and Control Group School Demographics

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<thead>
<tr>
<th>SCHOOL</th>
<th>GR</th>
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Note: * The gender totals vary slightly from the other demographic totals because the data were collected on separate dates within a three month time period. ** School officials estimate that Middle School One would qualify as a Title One School, but the application for Title One status has not been completed.

The experimental group consisting of two sixth grade classes, two seventh grade classes and two eighth grade classes receive forty-five minutes per day of regular math instruction using
the Louisiana Comprehensive Curriculum for the corresponding grade level and forty-five minutes per day of math instruction in the Sharpening Math Skills Lab. Scheduling of students for the lab was completed by the assistant principal prior to the beginning of the school year. All eighth grade students who scored at the Unsatisfactory level on the mathematics portion of the iLEAP were selected for participation in the Sharpening Math Skills Lab. Additional eighth graders who scored Approaching Basic were non-systematically chosen at random by the assistant principal to round out the class rosters. Seventh grade students chosen for participation were randomly selected among the Unsatisfactory and Approaching Basic students by the assistant principal. Due to the fact that iLEAP data for incoming sixth grade students was incomplete at scheduling time, the assistant principal inadvertently scheduled a few sixth graders who scored in the Basic, Mastery, and Advanced levels. As test data became available, these students were transferred out of the lab within the first three weeks of participation and replaced by low performing students.

Control Groups

The control groups are comprised of 162 math-delayed students from Middle School Two (113 students) and Middle School Three (49 students). The demographics of the control group are shown in Table 3.1. The control groups consist of the sixth, seventh, and eighth grade math-delayed students from both schools in which both the iLEAP and Scantron Performance Series test data were available. Control groups were selected based on the recommendation of the school district middle school math master teacher corps who are very familiar with the academic achievement levels and demographics of each school.
Table 3.2  Study Participants Demographics

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and are not randomly assigned. The internal validity threat of selection is handled through an Analysis of Covariate (ANCOVA) design in which the Scantron Performance Series pretest scale scores for all three groups are used for statistical control. The mathematics scale score data collected from the October and January sessions of the Scantron Achievement series will be separately analyzed for differences between the experimental and both control groups. More data will be collected from the experimental group. These will include pre and posttest of student spatial visualization ability, student attitude toward math inventory, classroom observation on levels of student engagement and learner interaction with the multimedia instructional design features, and case studies.

Data Collection Instruments

Quantitative instruments for this study are the iLEAP: Integrated Louisiana Educational Assessment Program test, Scantron Performance Series Mathematics Test, Scantron Achievement Series Mathematics Test, Wheatley Test of Spatial Visualization (Wheatley, 1996), and the Attitudes Toward Mathematics Inventory (ATMI) (Tapia, 1996). The qualitative instruments are The Louisiana Systemic Initiatives Program Classroom Observation Protocol (LaSOP), the Principles of Instructional Design Observation Protocol (PIDOP) and The Sharpening Math Skills Lab Student Case Study Interview Protocol.

Mathematics Academic Achievement Tests for Experimental and Control Groups

Testing battery components for both the experimental and control groups include the Integrated Louisiana Assessment Program (iLEAP), Scantron Performance Series and two Scantron Achievement Series mathematics tests.

iLEAP: Integrated Louisiana Assessment Program

The Integrated Louisiana Educational Assessment Program test (iLEAP) which is Louisiana’s state criterion and norm-referenced mandated test was used to determine initial
placement of students in the Sharpening Math Skills Lab. This instrument was also used along with the Scantron Performance Series data to compare the student achievement levels of the control groups with the experimental group.

According to the Louisiana Department of Education (LADOE), The Short Form of the Iowa Test of Basic Skills comprises the norm referenced portion of the test which compares the performance of Louisiana students with those from across the nation. The NRT components augmented with items specifically developed to align with the Louisiana Grade-Level Expectations (GLEs). These additional augmented GLE-based items combine with the Iowa Test items that align with GLEs to form the criterion-referenced test (CRT) component of the iLEAP. The difference between the two components (NRT and CRT) is the manner in which test results are interpreted. The two components yield two types of test scores: scores that represent students’ performance according to the Louisiana state standards (CRT scores) and scores that represent students’ performance compared to the national norms (NRT scores).

<table>
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<tr>
<th>Achievement Level</th>
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<td>394 - 500</td>
<td>421 - 500</td>
</tr>
<tr>
<td>Mastery</td>
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<td>358 - 393</td>
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</tr>
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<td>Unsatisfactory</td>
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<td>100 - 247</td>
<td>100 - 254</td>
</tr>
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</table>

Note: The data source for this table is the Louisiana Department of Education (2007)

The iLEAP Math tests are administered at grades 3, 5, 6, 7, and 9. Student scores are not used to determine advancement to the next grade. The LEAP, which only contains criterion referenced test items, is given in grades 4 and 8 and is used to determine whether students will be promoted to the next grade level. The mathematical strands measured on the iLEAP and LEAP tests include Number and Number Relations, Algebra, Measurement, Geometry, Data Analysis,

Students participating in this study are sixth, seventh, and eighth grade students who have iLEAP scores in the Unsatisfactory and Approaching Basic scaled-score range based on their respective fifth, sixth, and seventh grade Spring 2007 test results. Table 3.3 displays the range of scores for each of the iLEAP levels: Unsatisfactory, Approaching Basic, Basic, Mastery, and Advanced.

Scantron Performance and Achievement Series Tests

Students from all three middle schools were also evaluated by the Scantron Performance Series Mathematics Test at the beginning of the 2007 school year. Scantron Achievement Series will be administered for student mastery of one set of GLEs in October, 2007 and for another set of GLEs in January 2008. The Performance Series test is a standardized, adaptive, web-based test in which student data is immediately available online. The standardized Achievement Series tests are linear, paper and pencil tests which are electronically scored at each school site. Achievement Series test results are scanned at the school site and saved in Excel format.

In both the Performance Series and Achievement Series tests students are evaluated on their performance in the mathematical strands of Numbers and Operations, Algebra, Geometry, Data Analysis and Probability, and Measurement. Test items for all strands were developed specifically for the school district based on Louisiana GLEs by Scantron psychometricians.

Scantron scale scores, standard item pool, and grade level equivalent scores from the Performance Series test were used as a diagnostic instrument to determine the placement level and curriculum customization of students in the Larson Intermediate Math series and will be used for the purposes of this study to determine the level of equivalency for the experimental and control groups.
The scaled score from both Performance Series and Achievement Series will be used to compare student achievement in this study as it is a reliable estimate of the student’s ability using the statistical Rasch model in which the probability of a specified response (e.g. right/wrong answer) is modelled as a function of person and item parameters. Values can range from 1300 to 3700 in Performance Series. The scaled score is a yardstick to compare students to each other or themselves across time (Scantron, 2007).

Reliability refers to the degree that true scores are free from errors of measurement (American Educational, 1999). These measurements are consistent when repeated in a population of examinees. A more meaningful index for both classical and Item Response Theory (IRT) based assessment tools is the standard error of measurement. This measure of precision specifies a confidence interval within which an examinee’s measure will fall with repeated assessments. According to Scantron (2007), in Computer Adaptive Testing (CAT), where examinees are exposed to different sub-sets of items, the only meaningful way to express an instrument's reliability or precision is through the error associated with an examinees’ ability estimate, that is, the standard error of measurement. Scantron’s goal is a standard error of measurement of less than 0.30 logits for each examinee. This is roughly equivalent to a conventional reliability coefficient of 0.91.

The Standards for Educational and Psychological Testing (1999) define validity as the degree to which accumulated evidence and theory support specific interpretations of test scores entailed by proposed uses of a test. Scantron’s (2007) validity research has accumulated and categorized evidence for content validity, item validity, and sampling validity. Content validity refers to the degree to which a test measures an indicated content area and is determined through the examination of the concepts of item validity and sampling validity (Scantron, 2007). Item validity focuses on the degree to which test items are relevant in measuring the desired content
area and is determined through a comparison of individual state standards, state assessment programs, and the National Assessment of Educational Programs (NAEP). Prospective items are subjected to external evaluation by a panel of content area experts. Items are reviewed for item alignment with the indicated skill at the appropriate grade level, item content and quality, item bias, and gender count for passive/active voice. Sampling validity is determined through an item selection algorithm to ensure that each examinee’s Performance Series experience includes items that span the given content area. To illustrate the concepts of item and sampling validity of Performance Series in a more quantitative manner, Scantron (2007) has examined the correlation of examinee scores between the component testlets within each content area. The majority of testlets indicate a fairly good (>0.65) correlation coefficient.

Additional Measurements for the Experimental Group

The experimental group will also be evaluated both quantitatively and qualitatively for contributing factors to student achievement. Students in the experimental group will be pretested and posttested for student spatial visualization ability using the Wheatley Test of Spatial Visualization as this has been linked to overall problem solving ability. The experimental group will also take the Attitudes Toward Math Inventory (ATMI) to measure student attitudes and motivation. Observations of student behavior and levels of engagement will also be conducted using the The Louisiana Systemic Initiatives Program (LaSIP) Classroom Observation Protocol (LaSOP) and The Sharpening Math Skills Lab Student Case Study Interview Protocol. The principles of instructional design in the treatment software programs will be evaluated by the Principles of Instructional Design Observation Protocol (PIDOP).

**Wheatley Spatial Ability Test (WSAT) Form B**

The WSAT (Wheatley, 1996) measures mathematics potential and the visualization skills of a student. The test measures student ability to mentally rotate images of geometric figures.
This dimension of spatial ability has been shown to be highly related to students’ mathematical understanding and potential for mathematical thinking. Wheatley has observed and created models for improving the visualization sense of students in the teaching and learning of geometry and transformations (1991, 1996). The WSAT is designed to identify students who may not do well with arithmetical computations, but still have some mathematical potential. When students are encouraged to use imagery, their mathematical power is greatly increased (Wheatley, 1991).

The test is comprised of 20 sets of figures in which the student must compare the first figure in the series with the other five to determine whether they are simply rotations of the original figures or if the new figure has been reflected and then rotated. For each of the 100 comparisons, students are to select Y for rotations or N for reflected – rotated figures. Students have eight minutes to answer as many as they can. Ignoring incomplete answers, scoring is based on a formula of subtracting half of the incorrect responses from the correct responses and then applying the results to a table of norms.

**Attitudes Toward Mathematics Inventory (ATMI)**

In a study of the Attitudes Toward Mathematics Inventory (ATMI), Tapia (1996) recommended that the instrument be utilized to obtain useful information that relates to gender, ethnic, background, and mathematics achievement to the test. The revised ATMI contains 40 items measuring student confidence, anxiety, value, enjoyment, motivation, and parent/teach expectations. Items are constructed using a Likert-scale format with the anchors: 1 - strongly disagree, 2 – disagree, 3 – neutral, 4 – agree, and 5 – strongly agree. The score is the sum of ratings.

Psychometric properties have been determined to be sound (Tapia & Marsh, 2004). To estimate internal consistency of the scores, a Cronbach alpha coefficient was calculated. After an
item-deletion process, alpha reached a value of .97 with a standard error of measurement of 5.67. Item-to-total correlations indicate good internal consistency. In terms of content validity, the factor structure of the ATMI covers the domain of attitudes toward mathematics. Additionally test items relate to the variables of confidence, anxiety, value, enjoyment, and motivation. This structure is explained by the four-factor model supporting different interpretations for students’ self-confidence, value, enjoyment and motivation as underlying dimensions toward mathematics.

The Louisiana Systemic Initiative Program Student Observation Protocol (LaSOP)

The Louisiana Systemic Initiative Program (LaSIP) was created under a directive from the Board of Elementary and Secondary Education (BESE) of Louisiana to design and conduct professional development combined with leadership training for teachers. The LaSIP Student Observation Protocol was developed as part of this initiative and is a web-published, copyright free instrument available to educators. The original instrument focuses on collecting time-frequency data on student engagement and has been modified to collect qualitative data on student motivation and engagement as evidenced by student expressions of satisfaction on successful performance, asking questions, and discussing content-related issues with peers, making efforts in tackling difficult questions, and commenting positively on the learning activities.

Principles of Instructional Design Observation Protocol (PIDOP)

The Principles of Instructional Design Observation Protocol (PIDOP) was designed by the researcher based upon the six principles of instructional design identified by Moreno and Mayer (2000). The instrument is comprised of twelve indicators of design features which are keyed to the six principles of instructional design: split attention principle, modality principle, redundancy principle, temporal principle, coherence principle, and the spatial contiguity principle. The researcher marks each time a specific design feature is observed during student
use of the program software. The instrument also has an area for the researcher to make qualitative observation notes.

**Sharpening Math Skills Lab Student Case Study Interview Protocol**

Comprised of ten questions for six individual case study interviews, the instrument is designed to gauge student attitudes and perceptions of mathematics instruction in the Sharpening Math Skills Lab. The questions are also designed to elicit perceptions from the students on which multimedia features provide motivation or facilitate greater learning.

**Procedures**

**Preparation for Research**

The researcher attended sessions held by the school district mathematics consultant and a Scantron test item developer to learn about the Scantron Performance Series and Achievement Series test content to determine whether the tests could be used as a pretest/posttest design or as a factorial design. It was learned that the Performance Series given at the beginning of the school year is a diagnostic test encompassing all of the Grade Level Equivalents (GLEs). The Achievement Series Tests given twice during the year each emphasize a separate set of GLEs. The October test session covers the GLEs contained in the first few units of the Louisiana Comprehensive Curriculum. The January test session emphasizes the remaining GLEs. Student performance data on these tests are to be used by teachers to help students prepare for the March iLEAP. For the purposes of this study student performance data from the experimental group and the two control groups will be compared to show if a difference exists between the technology-mediated instructional method and traditional mathematics instruction. The researcher also spent a day working with the Sharpening Math Skills Lab consultant learning to enroll students in each program and configure curricula for each student based on their Scantron Performance Series test scores in the Larson Intermediate Math Series.
Consent to Participate

An application to the school district’s research and assessment office to conduct research using data collected from students in three middle schools was completed. Permission was secured from the participating school district superintendent and instructions were sent to the parish assessment offices to provide the researcher with access to data from all three schools. As students are not requested to participate in activities outside the scope of their normal educational program, it was not required by the parish that individual consent forms be completed by students.

The Louisiana State University Internal Review Board (IRB) application was completed by the investigator and submitted along with a copy of the abstract.

Consent to Use Instruments

Use of Scantron Performance and Achievement Series Tests

Licensing for the Scantron Performance and Achievement Series Tests was purchased by the local school district for their discretionary use of student data. The researcher has specific permission to conduct research by the school district which includes usage of this test data.

Use of the WSAT

The researcher purchased the WSAT which is available commercially through Mathematics Learning at http://www.mathematicslearning.org.

Use of the ATMI

Permission for use of the ATMI was granted by Dr. Martha Tapia, instrument developer via personal communication on October 11, 2007. Dr. Tapia also provided the researcher with an updated copy of the instrument.
Use of the LaSOP

The Louisiana Systemic Initiatives Program (LaSIP) Classroom Observation Protocol (LaSOP) is published under the auspices of the Louisiana Department of Education and is copyright free. Copies may be obtained from available from http://www.lasip.org/downloads/LaSOPsample.doc

Use of the PIDOP

The Principles of Instructional Design Observation Protocol (PIDOP) was created by the researcher based on the six principles of instructional design identified by Dr. Roxana Moreno and Dr. Richard Mayer (2000). Permission was granted by Dr. Moreno and Dr. Mayer via personal communication on January 4, 2008 to use this information for research purposes.

Use of the Sharpening Math Skills Lab Student Case Study Interview Protocol

The case study questionnaire was developed by the researcher.

Data Analysis

Data gathered in this study are primarily quantitative: scale scores from the Scantron Performance Series and Achievement Series, Likert Scale of Summated Ratings from the ATMI, and normed scores from the WSAT. Qualitative data will be collected through the use of the LaSOP, PIDOP, and the Sharpening Math Skills Lab Student Case Study Interview Protocol.

1. Do students who scored in the Unsatisfactory or Approaching Basic levels on the iLEAP (Spring 2007) who participate in the Sharpening Math Skills Lab interactive multimedia mathematics instructional activities make on the Scantron Mathematics Tests than other low-performing students who do not participate in the program?

Using two Analysis of Covariance (ANCOVA) procedures, the mathematics scale score data collected from the October and January sessions of the Scantron Achievement series will be separately analyzed for differences between the experimental and the control groups. The results
of the Scantron Performance Series which was administered at the beginning of the school year will serve as a covariate to remove the effects of pre-existing individual differences in the non-randomized experimental and control groups.

2. Will participation in the Sharpening Math Skills Lab interactive multimedia mathematics instructional activities increase the spatial visualization ability of students as demonstrated by performance on a pretest and posttest of Wheatley’s Spatial Ability Test?

The WSAT will be administered to the experimental population of students early in the semester and again at midterm to determine if there were changes in their spatial visualization ability as a result of participation in Computer Assisted Instruction for mathematics. Using the Middle School One student’s WSAT scores on the pre and post test, a dependent $t$ test will be used to determine the differences between the beginning and the end of the study.

3. Is there a correlation between math-delayed student problem solving ability and their spatial visualization ability?

The Scantron Achievement Series Tests are comprised of in context or real world problem solving items across five strands. Using the January scale score results from Scantron testing and the WSAT normed scores, a Pearson $r$ and linear regression analysis will be run to determine the nature of the relationship between the experimental groups ability to problem solve and their spatial visualization ability.

4. What are the specific multimedia principles of instructional design implemented in the software program interfaces in the Sharpening Math Skills Lab and what are the student perceptions of these features?

The PIDOP and The Sharpening Math Skills Lab Student Case Study Interview Protocol will be used by the researcher to address this question. The PIDOP instrument identifies the specific
multimedia design features of the programs used in the Sharpening Math Skills Lab through classroom observations. The Sharpening Math Skills Lab Student Case Study Interview Protocol will be used to identify individual case study perceptions of the effectiveness of the software program interfaces in mathematics instruction. The case study participants are comprised of a purposive sample of two students from each grade level for a total of six students.

5. What are the attitudes, perceptions, and classroom behaviors of math-delayed students who participate in the Sharpening Math Skills Lab concerning mathematics learning experiences?

This question will be answered using both quantitative and qualitative analysis. The quantitative component is the measure of the scores on the ATMI which is in Likert Scale of Summated ratings format and will be administered at the end of the study. The score for the ATMI is the sum of the ratings which will be presented in tables. (On the reversed items, adjustment will be made for the appropriate value for data analysis.) The qualitative instrument is The Louisiana Systemic Initiatives Program (LaSIP) Classroom Observation Protocol (LaSOP). Observed levels of student engagement will be used to confirm and/or explain ATMI ratings scores.
CHAPTER FOUR

QUANTITATIVE RESEARCH FINDINGS

The purpose of this study is to determine if the Sharpening Math Skills Lab technology-mediated mathematics instructional practices for math-delayed middle school students have positive effects on their mathematics achievement, spatial visualization ability, engagement in learning, attitudes toward mathematics instruction, and perceptions of the effectiveness of multimedia principles of instruction. Of these, three areas were measured quantitatively: student achievement, spatial visualization, and attitudes toward mathematics instruction. These quantitative research findings are presented in this chapter with the details of the data collection procedures, the quantitative results, and an analysis of the findings.

Student Achievement

One of the purposes of this study is to measure the effects of the Sharpening Math Skills Lab on student achievement. Specifically, the results of the statistical procedures presented in this section should determine if students who scored in the Unsatisfactory or Approaching Basic levels on the iLEAP (Spring 2007) and participate in the Sharpening Math Skills Lab using FASTTMath and iSucceed interactive multimedia mathematics instructional activities make greater gains on the Scantron Mathematics Tests than other low-performing students who do not participate in the program.

Data Collection

To address the issue of student achievement, data from three mathematics achievement tests which were administered throughout the school district, including both the experimental and control groups, were collected. A summative Scantron Performance Series mathematics test was administered in September 2007 and two formative Scantron Achievement Series mathematics tests were administered in October 2007 and January 2008. These assessments are
described in detail in Chapter Three. Access to the participating schools’ Scantron website was made available to the researcher for data collection purposes from the school district’s assessment office.

Statistical Procedures

To determine the effects of the Sharpening Math Skills Lab, two Analysis of Covariance (ANCOVA) procedures were performed using Statistical Package for Social Sciences (SPSS) Version 14.0. ANCOVA is a statistical method that can be used to equate groups that are found to differ on a pretest or some other variable or variables (Johnson & Christensen, 2004). Using ANCOVA, the researcher can increase the precision of the research by partitioning out the variation attributed to the covariate, which results in a smaller error variance (Hinkle, Wiersma, & Jurs, 2003).

Quantitative data used to address research question one are three Scantron mathematics achievement tests administered in September 2007, October 2007, and January 2008. The mathematics achievement scores of math-delayed students in the experimental group (N = 109) and the control groups (N = 162) were compared twice using the September 2007 Scantron Performance Series mathematics scale scores as the covariate and the October 2007 and January 2008 Scantron Achievement Series as the dependent variables for each ANCOVA. The teaching method (regular math instruction or multimedia mathematics instruction) was used as the categorical variable and the Scantron Performance Series Test percent correct scores as the continuous variable.

The decision to use two separate ANCOVAs was based on the fact that the October 2007 and January 2008 Scantron Achievement series tests are considered pseudo independent by the test developers. The Scantron Achievement Series tests measure the same mathematical standards, but do not address all of the same Grade Level Expectations (GLEs) associated with
each mathematical strand, making them unreliable as pretest and posttest measurement instruments.

Descriptive statistics for the first ANCOVA comparing the means of the Sharpening Math Skills Lab students and the regular mathematics instruction students are displayed in Table 4.1. The mean of the regular mathematics group is slightly higher than the mean of the Sharpening Math Skills Lab students. ANCOVA results which compare the control group and experimental group’s October 2007 Scantron Achievement Series test results with the September 2007 Scantron Performance Series Test as the covariate are reported in Table 4.2. Levene’s Test of Equality of Error Variances, sometimes referred to as homogeneity of variances, revealed a significance level of .004 (p < 0.05) indicating that variances were not equal across groups; however, the differences are considered slight.

Table 4.1  Descriptive Statistics for the October 2007 Scantron Achievement Series Dependent Variable ANCOVA

<table>
<thead>
<tr>
<th>Math Instructional Method</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharpening Math Skills Lab</td>
<td>33.32</td>
<td>12.54469</td>
<td>109</td>
</tr>
<tr>
<td>Regular Mathematics</td>
<td>36.31</td>
<td>9.65707</td>
<td>162</td>
</tr>
<tr>
<td>Total</td>
<td>35.10</td>
<td>10.98674</td>
<td>271</td>
</tr>
</tbody>
</table>

The results of the first ANCOVA (Table 4.2) using the October 2007 Scantron Achievement Series mathematics percent correct scores as the dependent variable and the September 2007 Scantron Performance Series mathematics scale scores as the covariate reports no significant difference in student scores between the teaching methods. ANCOVA results show a significance level of .121 indicating no significant difference between the two teaching
methods at an alpha criterion for significance set at $\alpha = 0.05$, corresponding to a 95% confidence level.

Table 4.2 Results for the October 2007 Scantron Achievement Series Dependent Variable ANCOVA

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>2971.277</td>
<td>2</td>
<td>1485.638</td>
<td>13.442</td>
<td>.000</td>
<td>.091</td>
</tr>
<tr>
<td>Intercept</td>
<td>290.686</td>
<td>1</td>
<td>290.686</td>
<td>2.630</td>
<td>.106</td>
<td>.010</td>
</tr>
<tr>
<td>Scantron Performance</td>
<td>2390.553</td>
<td>1</td>
<td>2390.553</td>
<td>21.630</td>
<td>.000</td>
<td>.075</td>
</tr>
<tr>
<td>Method</td>
<td>266.860</td>
<td>1</td>
<td>266.860</td>
<td>2.415</td>
<td>.121</td>
<td>.009</td>
</tr>
<tr>
<td>Error</td>
<td>366557.260</td>
<td>268</td>
<td>110.522</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>32591.284</td>
<td>270</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The descriptive statistics for the January 2008 Scantron Achievement Series dependent variable ANCOVA are presented in Table 4.3 and report that the mean of the regular mathematics instruction remains higher than the mean of the Sharpening Math Skills Lab students. Levene’s Test of Equality of Error Variances reveals a significance level of .070 meaning the error variance of the dependent variable is equal across groups.

The second ANCOVA (Table 4.4) using the January 2008 Scantron Achievement Series mathematics percent correct scores as the dependent variable and the September 2007 Scantron Performance Series mathematics percent correct scores as the covariate also reports no significant difference in student scores between the teaching methods. Tests of between-subjects effects are displayed in Table 4.4. The significance level of .095 ($p < .05$) indicates there is no significant difference between the instructional methods.
Table 4.3  Descriptive Statistics for the January 2008 Scantron Achievement Series
Dependent Variable ANCOVA

<table>
<thead>
<tr>
<th>Math Instructional Method</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharpening Math Skills Lab</td>
<td>37.6606</td>
<td>13.7551</td>
<td>109</td>
</tr>
<tr>
<td>Regular Mathematics</td>
<td>41.35.86</td>
<td>11.25935</td>
<td>162</td>
</tr>
<tr>
<td>Total</td>
<td>39.8712</td>
<td>12.43285</td>
<td>271</td>
</tr>
</tbody>
</table>

Table 4.4  ANCOVA Results for Dependent Variable January 2008 Scantron Achievement Series Test

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>5071.240</td>
<td>2</td>
<td>2535.620</td>
<td>18.534</td>
<td>.000</td>
<td>.122</td>
</tr>
<tr>
<td>Intercept</td>
<td>812.216</td>
<td>1</td>
<td>812.216</td>
<td>5.937</td>
<td>.015</td>
<td>.022</td>
</tr>
<tr>
<td>Scantron Performance</td>
<td>4180.138</td>
<td>1</td>
<td>4180.138</td>
<td>30.555</td>
<td>.000</td>
<td>.102</td>
</tr>
<tr>
<td>Method</td>
<td>384.572</td>
<td>1</td>
<td>384.572</td>
<td>2.811</td>
<td>.095</td>
<td>.010</td>
</tr>
<tr>
<td>Error</td>
<td>36664.216</td>
<td>268</td>
<td>136.807</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>472547.950</td>
<td>271</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>41735.455</td>
<td>270</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In conclusion, the students who scored in the Unsatisfactory or Approaching Basic levels on the iLEAP (Spring 2007) who participate in the Sharpening Math Skills Lab using FASTTMath and iSucceed interactive multimedia mathematics instructional activities do not demonstrate greater gains on the Scantron Mathematics Tests than other low-performing students who do not participate in the program.
Spatial Visualization

Another purpose of this study is to assess two aspects of the spatial visualization skills of the experimental group. The first purpose of this section is to determine whether participation in the Sharpening Math Skills Lab using FASTTMath and iSucceed interactive multimedia mathematics instructional activities increase the spatial visualization ability of students. The second purpose of this section is to determine if there is a correlation between math-delayed student problem solving ability and their spatial visualization ability.

Data Collection

The Wheatley Test of Spatial Ability (WSAT) which is described in Chapter Three, was administered to the experimental group (N = 109) in October 2007 and again in January 2008. The results of the WSAT are used to address two spatial visualization research issues: (1) the level of student spatial visualization growth and (2) the level of correlation between student spatial visualization and mathematics achievement. To address the first issue the WSAT pretest and posttest measurements are used to determine the level of student spatial visualization growth. To address the second issue, the amount of student spatial visualization growth is determined by subtracting the WSAT pretest scores from the posttest scores and correlating the results with student mathematics achievement scores. The student mathematics achievement scores used in the correlation statistical procedures are from the Scantron Performance Series mathematics test which is described in Chapter Three.

The WSAT consists of 20 sets of visual problems in which a student examines the first shape in the set and then determines whether each of the five subsequent shapes is a rotation or a combination of a flip and rotation. Following the procedures established by Grayson Wheatley, the instrument developer, students complete as many of the sets as possible in eight minutes. To derive a national percentile score, the formula Score = C – (1/2) x W, where C is the number of
correct responses and W is the number of incorrect responses was used. Half of the number of incorrect responses was subtracted from the number of correct responses and the resulting number was applied to a corresponding national percentile scale.

Statistical Procedures

Table 4.5  Wheatley Spatial Ability Test Paired Samples Test

<table>
<thead>
<tr>
<th>Paired Differences</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>Std. Deviation</td>
</tr>
<tr>
<td>Pair 1 WSAT Oct. '07 WSAT Jan. '08</td>
<td>22.266</td>
</tr>
</tbody>
</table>

Paired Samples

To determine whether the students in the experimental group increased their spatial visualization skills, a dependent $t$ test or paired sample statistical procedure was performed using the WSAT pretest-posttest measurement data.

Using SPSS 14.0 to perform the dependent $t$ test, the results (Table 4.5), reveal a significance level of .000 ($p < .05$), indicating that the Sharpening Math Skills Lab student spatial visualization ability increased significantly over the three month period.

In conclusion, the significance level of .000 ($p < .05$) results of the dependent $t$ test statistical procedure indicate that participation in the Sharpening Math Skills Lab using FASTTMath and iSucceed interactive multimedia mathematics instructional activities significantly increases the spatial visualization ability of students as demonstrated by performance on a pretest and posttest of Wheatley’s Spatial Ability Test.
Correlation

To determine if a correlation between student achievement and spatial visualization ability exists, a Pearson product-moment correlation coefficient (Pearson $r$) and linear regression analysis were performed using SPSS 14.0. Pearson $r$ is the correlation coefficient used most often in the behavioral sciences to determine the extent to which two sets of data are related (Hinkle, Wiersma, & Jurs, 2003). Regression analysis is also a statistical procedure which explores the relationship between variables and determines the causal effect that one variable has on another (Hinkle, Wiersma, & Jurs, 2003). The findings from these statistical procedures are presented in detail as the resulting statistical significance warrants careful consideration.

The two sets of quantitative data used in determining if there is a correlation between math-delayed student problem solving ability and their spatial visualization ability were the difference between the WSAT pretest and posttest scores (WSAT Post-Pre) and the September 2007 Scantron Performance Series scale scores (ScanPerf). The results are displayed in Table 4.6. The significance level of 0.014 is considered statistically significant at the alpha criterion level of $\alpha = 0.05$, with a confidence level of 95%.

Table 4.6 displays the correlation coefficient (.235) between the ScanPerf mathematics scale scores and the WSAT Post-Pre scores. A correlation coefficient is a number that ranges from -1.0 to +1.0 and indicates how closely the relative positions of two or more variables agree with one another. This positive correlation indicates that low values on the first variable correlate with low values on the second variable, and high values on the first variable, in general, correlate with high values on the second variable.
Table 4.6 Pearson $r$ Correlation of WSAT Posttest - Pretest Scores and Scantron Performance Series Mathematics Scale Scores

<table>
<thead>
<tr>
<th>WSAT Posttest - Pretest</th>
<th>Scantron Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Correlation</td>
<td>1</td>
</tr>
<tr>
<td>Sig. (2 tailed)</td>
<td>.235*</td>
</tr>
<tr>
<td>N</td>
<td>109</td>
</tr>
<tr>
<td>Scantron Performance</td>
<td>.014</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>.235*</td>
</tr>
<tr>
<td>Sig. (2 tailed)</td>
<td>1</td>
</tr>
<tr>
<td>N</td>
<td>109</td>
</tr>
<tr>
<td></td>
<td>271</td>
</tr>
</tbody>
</table>

Note: * Correlation is significant at the 0.05 level (2-tailed).

In terms of the measurement instruments this is interpreted to mean that in a number of cases students who performed the lowest on the ScanPerf mathematics test tended to demonstrate the least amount of growth on the WSAT Post-Pre between October 2007 and January 2008. Conversely, those students who demonstrated the most growth on the WSAT Post-Pre between October 2007 and January 2008 tended to have the higher scores on the September 2007 Scantron Performance Series mathematics test.

The model summary table (Table 4.7) shows information related to the correlation between the predictor or constant variables (WSAT Post-Pre) and the dependent variable (ScanPerf). The R value is the Pearson correlation which was introduced in Table 4.6. R-square ($R^2$) represents the proportion of the variation of the dependent variable accounted for by the independent variable. This coefficient of determination is relatively low at .055 which means that 5.5 percent of the variation of ScanPerf is explained by WSAT. The standard error of the estimate (the estimate of the average spread of the residuals or deviations) around the regression line is 135.347.
Table 4.7  Linear Regression Analysis Model Summary

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R square</th>
<th>Adjusted R square</th>
<th>Std. Error of the Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.235&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.055</td>
<td>.047</td>
<td>135.347</td>
</tr>
</tbody>
</table>

<sup>a</sup> Predictors (Constant) WSAT Posttest - Pretest

An Analysis of Variance (ANOVA) statistical procedure associated with the linear regression analysis was performed and the results are displayed in Table 4.8. ANOVA for regression consists of calculations that provide information about levels of variability within a regression model and form a basis for tests of significance. In this type of ANOVA table, the names for the equivalent sums of squares (SS) are different. The between-group SS of the ANOVA are represented as regression SS and the within-group SS of the ANOVA are represented as residual SS in the regression model.

The ANOVA indicates a significance level of .014 which is statistically significant at an alpha level of 0.05. This model shows the total sum of squared deviations from the overall sample mean (2075093.8) which is the measure of overall variation in the dependent variable (ScanPerf). Of this overall samples mean, the ANOVA model attributes a combined regression sum of squares of 114975.82 to the independent variable (WSAT Post-Pre). The significance level associated with the F-test (F = 6.276; p < 0.05) indicates that the linear trend observed in the sample is significantly different from zero.
Table 4.8  Regression Analysis ANOVA of WSAT Posttest - WSAT Pretest Scores and September 2007 Scantron Performance Series Test Mathematics Scale Scores

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>114975.82</td>
<td>1</td>
<td>114975.822</td>
<td>6.276</td>
<td>.014</td>
</tr>
<tr>
<td>Residual</td>
<td>1960118.0</td>
<td>107</td>
<td>18318.860</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2075093.8</td>
<td>108</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Predictors Constant WSAT Post – Pre
b. Dependent Variable ScanPerf mathematics scale scores

Table 4.9  September 2007 Scantron Performance Series Test Scores by WSAT Posttest - Pretest Regression Coefficient

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
</tr>
<tr>
<td>(Constant)</td>
<td>2368.448</td>
<td>16.843</td>
</tr>
<tr>
<td>WSAT Post - Pre</td>
<td>1.210</td>
<td>.483</td>
</tr>
</tbody>
</table>

Table 4.9 displays the unstandardized coefficients (B), which are the regression coefficients. For cross-sectional data, the regression coefficient for the predictor is the difference in response per unit difference in the predictor. For longitudinal data, the regression coefficient is the change in response per unit change in the predictor. Here, the ScanPerf scores differ 1.210 units for every unit difference in the WSAT Post-Pre scores.

The standard error section represents the standard errors of the regression coefficients. The standard error of the WSAT Post-Pre coefficient is .483. The standardized coefficient (Beta)
is reported as .235 and is derived by subtracting the sample mean from each piece of data and then dividing by the standard deviation. The \( t \) statistic for the WSAT Post-Pre is 2.505. These represent the ratio of the sample regression coefficient \( B \) to its standard error. The significance level for the \( t \) statistic is .014.

In summary, the Pearson \( r \) results indicate a small positive correlation (.235) between math-delayed student problem solving ability and their spatial visualization ability. Findings from the linear regression analysis produce an estimate that the ScanPerf math scores (dependent variable) account for 5.5% in the variation of the WSAT Post-Pre (independent variable) and that the September 2007 Scantron Performance Series mathematics scale scores differ 1.210 units for every unit difference in the Wheatley Spatial Ability Test January 2008 Posttest – October 2007 Pretest scores.

Student Attitudes and Behaviors

Information on attitudes and classroom behaviors of math-delayed students who participate in the Sharpening Math Skills Lab concerning mathematics learning experiences are presented in this section. This aspect of the study is addressed quantitatively through the results of the Attitude Toward Math Inventory (ATMI) and qualitatively through case studies. This section reports the quantitative results of the ATMI. The case studies are reported in the Collective Case Study section of Chapter Five.

Data Collection

The ATMI consists of forty statements in Likert Scale of Summated Ratings format in which the students select Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree. The experimental group students (\( N = 109 \)) were administered the inventory in January 2008 in a classroom setting with accommodations for varying student reading level abilities. The researcher placed a copy of the instrument on the overhead and read each item to the students,
pausing until each student had the opportunity to pencil in their response on their Scantron form. Students were also provided a copy of the instrument so they could read along with the teacher. There were no missing or incorrectly filled in responses due to careful administration of the inventory.

The forms were scanned using an Apperson Datalink scanner and the standard item analysis results were exported to Excel where the researcher sorted the responses by corresponding subscales. The forty items on the ATMI are categorized by subscales of self-confidence, value, enjoyment, and motivation. Eleven of the items were reversed on the inventory, but corrected for tabulation in the frequency tables.

**ATMI Results**

The self-confidence subscales (Table 4.10) reveal that the math-delayed students in the Sharpening Math Skills Lab are fairly evenly divided on their self-confidence in their mathematics ability. The percentage of students who lacked self-confidence in their ability was 35.7% which represents the strongly disagree and disagree scores combined. The percentage of students without a strong opinion in their abilities was 20.5%. Students who felt self-confident in their ability to do mathematics by selecting agree or strongly agree on the subscale indicators comprised 43.9%.

The value subscale frequencies are displayed in Table 4.11. Those students who agree and strongly agree indicate that 60.4% of the Sharpening Math Skills Lab students feel mathematics is personally meaningful to them. Students who did not express an opinion on the value of math numbered 16.4%. Those who felt that math was unimportant comprised 23.3% (disagree and strongly disagree).
Table 4.10  ATMI Self-confidence Subscales Frequencies

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 9*</td>
<td>24</td>
<td>21</td>
<td>17</td>
<td>27</td>
<td>20</td>
</tr>
<tr>
<td>Item 10*</td>
<td>22</td>
<td>13</td>
<td>27</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>Item 11*</td>
<td>12</td>
<td>22</td>
<td>24</td>
<td>23</td>
<td>28</td>
</tr>
<tr>
<td>Item 12*</td>
<td>12</td>
<td>22</td>
<td>18</td>
<td>25</td>
<td>32</td>
</tr>
<tr>
<td>Item 13*</td>
<td>17</td>
<td>22</td>
<td>27</td>
<td>31</td>
<td>12</td>
</tr>
<tr>
<td>Item 14*</td>
<td>33</td>
<td>27</td>
<td>19</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Item 15*</td>
<td>25</td>
<td>29</td>
<td>26</td>
<td>13</td>
<td>16</td>
</tr>
<tr>
<td>Item 16</td>
<td>23</td>
<td>11</td>
<td>15</td>
<td>25</td>
<td>35</td>
</tr>
<tr>
<td>Item 17</td>
<td>12</td>
<td>13</td>
<td>29</td>
<td>29</td>
<td>26</td>
</tr>
<tr>
<td>Item 18</td>
<td>16</td>
<td>24</td>
<td>23</td>
<td>31</td>
<td>15</td>
</tr>
<tr>
<td>Item 19</td>
<td>7</td>
<td>21</td>
<td>17</td>
<td>36</td>
<td>28</td>
</tr>
<tr>
<td>Item 20*</td>
<td>13</td>
<td>24</td>
<td>24</td>
<td>32</td>
<td>17</td>
</tr>
<tr>
<td>Item 21*</td>
<td>14</td>
<td>28</td>
<td>28</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>Item 22</td>
<td>20</td>
<td>24</td>
<td>19</td>
<td>26</td>
<td>20</td>
</tr>
<tr>
<td>Item 23</td>
<td>21</td>
<td>22</td>
<td>25</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>271</td>
<td>312</td>
<td>335</td>
<td>382</td>
<td>335</td>
</tr>
</tbody>
</table>

Percent 16.60% 19.10% 20.50% 23.40% 20.50%

Note: * Indicates corrected values of reversed inventory items.

Table 4.11  ATMI Value Subscales Frequencies

<table>
<thead>
<tr>
<th>Item</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1</td>
<td>6</td>
<td>6</td>
<td>20</td>
<td>34</td>
<td>43</td>
</tr>
<tr>
<td>Item 2</td>
<td>2</td>
<td>7</td>
<td>9</td>
<td>39</td>
<td>52</td>
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<tr>
<td>Item 4</td>
<td>5</td>
<td>7</td>
<td>12</td>
<td>30</td>
<td>55</td>
</tr>
<tr>
<td>Item 5</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td>35</td>
<td>39</td>
</tr>
<tr>
<td>Item 6</td>
<td>29</td>
<td>37</td>
<td>22</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>Item 8</td>
<td>33</td>
<td>33</td>
<td>23</td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Item 35</td>
<td>12</td>
<td>13</td>
<td>25</td>
<td>31</td>
<td>28</td>
</tr>
<tr>
<td>Item 36</td>
<td>8</td>
<td>9</td>
<td>21</td>
<td>34</td>
<td>37</td>
</tr>
<tr>
<td>Item 39</td>
<td>10</td>
<td>13</td>
<td>10</td>
<td>36</td>
<td>40</td>
</tr>
<tr>
<td>Totals</td>
<td>114</td>
<td>139</td>
<td>179</td>
<td>306</td>
<td>352</td>
</tr>
</tbody>
</table>

Percent 10.50% 12.80% 16.40% 28.10% 32.30%

Note: * Indicates corrected values of reversed inventory items.
Table 4.12  ATMI Enjoyment Subscales Frequencies

<table>
<thead>
<tr>
<th>ATMI Enjoyment Subscales</th>
<th>Frequencies (n=109)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>Item 3</td>
<td>11</td>
</tr>
<tr>
<td>Item 24</td>
<td>18</td>
</tr>
<tr>
<td>Item 25*</td>
<td>21</td>
</tr>
<tr>
<td>Item 26</td>
<td>14</td>
</tr>
<tr>
<td>Item 27</td>
<td>18</td>
</tr>
<tr>
<td>Item 29</td>
<td>14</td>
</tr>
<tr>
<td>Item 30</td>
<td>25</td>
</tr>
<tr>
<td>Item 31</td>
<td>32</td>
</tr>
<tr>
<td>Item 32</td>
<td>19</td>
</tr>
<tr>
<td>Item 33</td>
<td>13</td>
</tr>
<tr>
<td>Item 34</td>
<td>14</td>
</tr>
<tr>
<td>Totals</td>
<td>185</td>
</tr>
</tbody>
</table>

Percent 17% 14.80% 20.50% 26.30% 21.50%

Note: * Indicates corrected values of reversed inventory items.

Students in the Sharpening Math Skills Lab who enjoy mathematics (Table 4.13) outnumber those who do not by a ratio of approximately 5:3 (47.8% to 31.80%). Neutral students comprised 20.5% of the experimental group.

Table 4.13  ATMI Motivation Subscales Frequencies

<table>
<thead>
<tr>
<th>ATMI Motivation Subscales</th>
<th>Frequencies (n=109)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>Item 23</td>
<td>17</td>
</tr>
<tr>
<td>Item 28*</td>
<td>16</td>
</tr>
<tr>
<td>Item 32</td>
<td>13</td>
</tr>
<tr>
<td>Item 33</td>
<td>8</td>
</tr>
<tr>
<td>Item 34</td>
<td>20</td>
</tr>
<tr>
<td>Totals</td>
<td>74</td>
</tr>
</tbody>
</table>

Percent 13.60% 14.70% 21.50% 31.00% 19.30%

Note: * Indicates corrected values of reversed inventory items.
Table 4.14 indicates that slightly over half (50.3% positive responses) of the students who participate in the Sharpening Math Skills Lab are highly motivated to learn mathematics. Students lacking in motivation comprised 28.3%, while those who were neutral numbered 21.5%.

In summary, slightly over half (50.6%) of the students who participate in the Sharpening Math Skills Lab had a positive attitude about mathematics in general. A little less than one third of the class (29.78%) did not have a favorable attitude toward mathematics. The average percent of the students who remained neutral about mathematics was 19.73%. Of particular interest was the fact that 60.4% of the students value mathematics, but only 43.9% feel confident about their abilities in math. Slightly over half the class feels highly motivated in mathematics with an average of 50.3% students selecting agree or strongly agree on the motivation subscale inventory items. These feelings are closely matched in terms of enjoyment of mathematics, with 47.8% of students reporting that they enjoy learning math in the Sharpening Math Skills Lab.

Analysis of Findings

The quantitative results reported for an instructional and data collection period of five months on the effects of multimedia mathematics instruction in the Sharpening Math Skills Lab on student achievement, spatial ability, and student attitudes and behaviors are mixed. The results of two separate ANCOVAs demonstrate that students in the Sharpening Math Skills Lab in Middle School One did not display a higher level of mathematical achievement than their control group math-delayed counterparts in Middle Schools Two and Three. While the average means of the control group were slightly higher than the experimental group for each mathematics achievement assessment, no statistically significant difference in group levels was determined. These findings warrant further examination of the Sharpening Math Skills Lab software features and program implementation as well as regular mathematics instructional practices in Middle Schools One, Two, and Three.
Findings for student spatial ability were of greater interest as the experimental group students exhibited significant growth in their spatial visualization abilities over a three month period. A statistical significance level of .000 (p < .05) was displayed when the WSAT pretest and posttest scores were compared in a dependent t procedure. A Pearson r correlation between student spatial visualization growth (WSAT posttest minus pretest scores) and student mathematics achievement (Scantron Performance Series) resulted in a small positive correlation. Detailed examination of the relationship between student spatial ability and mathematics achievement in a linear regression analysis ANOVA revealed that the Scantron Performance math scores (dependent variable) account for 5.5% in the variation of the WSAT Post-Pre (independent variable). These results merit investigation of the effects of the specific principles of instructional design utilized in the software programs on student spatial visualization ability.

The ATMI frequency table results for the experimental group ranking the mathematics attitude subscales from greatest to least percentage of students responding favorably as value, motivation, enjoyment, and self-confidence. The value subscale was selected as the most important with 60.4% of students responding positively to those inventory indicators. The second highest subscale was motivation at 50.3% of the students selecting agree or strongly agree to those subscale items. Ranking third, the percentage of students who responded positively to the enjoyment indicators was 47.8%. The lowest of the four subscales was self-confidence, with only 43.9% of the students reporting favorably on their mathematics ability. From these findings it is evident that a slight majority of the experimental group students understand the importance of mathematics and are motivated to learn mathematics, but do not enjoy the subject or feel that they have the ability to master mathematics. These results indicate that the effects of student attitudes on learning mathematics on academic achievement should be closely examined.
CHAPTER FIVE
QUALITATIVE RESEARCH FINDINGS

To understand the Sharpening Math Skills Lab students’ engagement in learning, attitudes toward mathematics instruction, and perceptions of the effectiveness of multimedia principles of instruction, several qualitative evaluation tools were employed. Findings from individual and whole class observations using portions of The Louisiana Systemic Initiatives Program (LaSIP) Classroom Observation Protocol (LaSOP) and a multi-case study are presented in this chapter. The experimental group data collected with these observation protocols are reported with the corresponding research question. The individual data collected using the LaSOP and Principles of Instructional Design Observation Protocol (PIDOP) are embedded in the collective case study. The Attitudes Toward Math Inventory (ATMI) averages for the six case study participants are quantitative and are reported with the thematic analysis in this chapter to provide complete information.

Overview of Qualitative Methodology

The researcher in this study serves as the Sharpening Math Skills Lab project facilitator, therefore acting as a participant observer while collecting data using the observation protocols and for the collective case study. Participant-as-observer is a type of qualitative researcher in which the investigator spends extended time with the group as an insider and tells members they are being studied (Johnson & Christensen, 2004). As the participant observer in this study works closely with the study subjects on a daily basis, verification of the trustworthiness of the qualitative research is especially important. According to Lincoln and Guba (1985) trustworthiness is established through the constructs of credibility, transferability, dependability, and confirmability. These four qualitative constructs are described in greater detail in the following sections.
Credibility

The truth-value or credibility of a study is determined by examining the conclusions to determine if they make sense, adequately describe research participants’ perspective, and authentically represent the phenomena under study (Lincoln & Guba, 1985; Miles & Huberman, 1994). Credibility was established through the use of member checking of collective case study students, triangulation, consultation with experts in the field, and presentation of the results to stakeholders (teachers, school system officials, and donors) in the Sharpening Math Skills Lab Project.

Eliciting participant feedback through member checking allows for discussion of the researcher’s interpretations and conclusions with the actual participants and other members of the participant community for verification and insight (Johnson & Christensen, 2004). Triangulation or the corroboration of results with alternate sources of data (Lincoln & Guba, 1985) was achieved through interviews, observations, and document analysis. Documents include student cumulative academic records and software usage progress reports.

Transferability

Transferability seeks to determine if the results both relate to and can be transferred to other contexts. This is achieved through the use of criterion-based (LeCompte & Preissle, 1993) or purposeful sampling (Patton, 1987, 1990) as the cases were selected to provide the information needed to address the purpose of the research (Johnson & Christensen, 2004). The criteria used in selecting case studies included demonstrating growth on academic achievement and spatial visualization assessments, demographics, and educational placement. The research may also be transferred to another context through the use of thick description of contexts, perspectives, and findings gleaned from the participants’ experiences (Geertz, 1973). Through the use of observation notes made on the protocol forms and keeping records of procedures and
activities, descriptions included in the case studies provide enough detail to enable others to
decide whether the results are transferable to other contexts.

Dependability

Dependability is a judgment as to whether the research is consistent over time and across
researchers (Lincoln & Guba, 1985; Miles & Huberman, 1994). To enhance dependability of
the study an inquiry audit consisting of process notes, field notes, and evidence of data reduction
strategies was employed. Two Sharpening Math Skills Lab teachers who are also graduate
students serve as peer debriefers and were asked on a daily basis to comment on all aspects of the
study including data collection instrument development, collection, and analysis, selection of
case studies, and examination of results.

Confirmability

Confirmability enhances the trustworthiness of research by providing assurance that the
findings are reflective of the participant’s experiences and are not the result of researcher’s bias
or perceptions. Insuring that the findings are supported by the data and are internally coherent
was achieved through peer debriefing by the lab teachers who are also graduate students and
analysis of artifacts which include original student work, raw data and evidence of data reduction.

Student Behavior

This section addresses the specific classroom behaviors of math-delayed students who
participate in the Sharpening Math Skills Lab as they use the FASTTMath and Larson iSucceed
software programs. Levels of student engagement are gauged by observing and recording the
frequency of specific classroom behaviors.

Data Collection

The data collection instrument for student behavior is levels of student engagement
section of The Louisiana Systemic Initiatives Program (LaSIP) Classroom Observation Protocol
(LaSOP). Designed for observing in a variety of classroom settings, a portion of the LaSOP contains a matrix recording observations at five minute intervals for ranking levels of and recording specific criteria evidenced in instructional strategies, cognitive activities, and levels of student engagements. The mid portion provides for recording of elements of the lesson. As research question five relates to attitudes and specific classroom behaviors of the Sharpening Math Skills Lab students, only the results of the LaSOP levels of student engagement observation protocol indicators are reported in this section. The levels of student engagement indicators include Exp – Student expression of satisfaction on successful performance; Ask – Asking questions relating to the lesson; Dis – Discussing content-related issues with peers; Eff – Making efforts in tackling difficult questions; and Pos – Commenting positively on the learning activities.

Students were informally observed in the Sharpening Math Skills Lab as the participant observer’s job-embedded activities. A LaSOP evaluation was conducted for each class once per week over the course of twelve weeks.

Contextual Setting

Decorated with a sixteen foot wide fabric wall hanging of an ocean floor scene, the Sharpening Math Skills Lab is home to thirty multimedia computers and the dozens of middle schoolers who stream in and out throughout the school day, either coming from or heading to their regular math class. As the math teacher and the project facilitator circulate, students enter the classroom, take an assigned seat, don a pair of headsets, and open the round, lime green FASTTMATH software icon on the desktop and use the software to sharpen their math fact automaticity skills for ten minutes. From there students move to Larson Intermediate iSucceed Math where they spend the next thirty to thirty-five minutes working at their own pace through
lessons specifically designed for their own grade level, often with assistance and encouragement from their math teacher and the lab facilitator.

LaSOP Results

In this section, the results of the LaSOP are presented in narrative form accompanied by a quantitized table (Table 5.1) displaying the average ranks and average frequency of the descriptors recorded on the forms over the twelve weeks of observation.

Table 5.1 LaSOP Levels of Student Engagement Frequency Averages

<table>
<thead>
<tr>
<th>LaSOP Levels of Student Engagement</th>
<th>Instructional Minutes Per Class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FASTTMath</td>
</tr>
<tr>
<td>5 10 15 20 25 30 35 40 45</td>
<td>5</td>
</tr>
<tr>
<td>Rankings</td>
<td></td>
</tr>
<tr>
<td>3 - High</td>
<td>3</td>
</tr>
<tr>
<td>2 - Med</td>
<td>3</td>
</tr>
<tr>
<td>1 - Low</td>
<td>2</td>
</tr>
<tr>
<td>Average Rank Scores</td>
<td></td>
</tr>
<tr>
<td>3 3 2 3 3 3 3 2 1</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Descriptors</th>
<th>Average Frequency of Observed Behaviors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp</td>
<td>4 5 1 3 3 4 3 2 2</td>
</tr>
<tr>
<td>Ask</td>
<td>1 1 2 3 2 3 3 2 1</td>
</tr>
<tr>
<td>Dis</td>
<td>1 1 1 2 2 3 3 2 1</td>
</tr>
<tr>
<td>Eff</td>
<td>4 4 2 3 4 3 3 1 1</td>
</tr>
<tr>
<td>Pos</td>
<td>3 5 1 2 2 2 2 1 1</td>
</tr>
</tbody>
</table>

Quantitizing data involves converting qualitative data into numerical codes and then using statistical analysis techniques with the data (Tasakkori & Teddlie, 1998). The results presented in Table 5.1 reveal a daily pattern of student behavior in the Sharpening Math Skills Lab which is detailed in the narrative.
FASTTMath Results

Upon entering the Sharpening Math Skills Lab, students immediately begin working in FASTTMath which requires the type of intense concentration and task commitment (Eff) that is often seen by youngsters while playing a video game. With only 10 minutes of instructional time allotted, there is very little discussion or interaction (Dis) among students while they are individually engrossed in the math fact automaticity drills and games of FASTTMath. Occasional comments of students expressing (Exp) excitement over a particularly high score can be heard during this ten minute interval or disappointment that they have to repeat an entire set of facts because their time was not fast enough.

Generally, students do not ask (Ask) for assistance during FASTTMath, unless there is a technical issue with the computer or program. Most of the students in the class seem to enjoy FASTTMath and will continue to use the software until their teacher and/or lab facilitator encourages them to move on to the Larson iSucceed program (Pos). There are four students who have been observed trying to skip participation in FASTTMath on a regular basis because they find it very frustrating. These students are also habitually tardy to class.

Student levels of engagement during FASTTMath are ranked consistently as high as 75 to 100 percent of students are actively engaged in using the interactive multimedia software.

Larson iSucceed Results

The next phase in Sharpening Math Skills Lab activities is the Larson iSucceed software program. During the transition between software programs the level of student engagement drops to a two. The math teacher and project facilitator circulate among the students encouraging students to log-in to iSucceed and begin their individualized lessons. This is a crucial time during the lesson as students express (Exp) their desire to keep working in FASTTMath. Disciplinary concerns arise during transition, especially among the eighth graders
where there are three or four older male students in each of the two eighth grade classes who often vocalize their feelings of not being successful in math and their desire to not participate in the lab project. These young men have already repeated at least one grade and are functioning three or four grade levels behind their peers. It usually takes their math teacher and the project facilitator several minutes to get them and the students who are distracted by this behavior focused on working with the iSucceed software. Occasionally disciplinary action on the part of an administrator is needed to settle these groups of eighth graders.

As the class begins to focus on the iSucceed software lesson modules, problem solving or assessments, the noise level diminishes and the level of student engagement rises to a three and remains a three for the next fifteen minutes. Students are observed putting forth a great deal of effort (Eff) during this peak quarter hour. The high level of engagement is evidenced by an increase in the frequency of which students ask the adults or peers for assistance with problem solving (Ask) or discuss answers to problems (Dis). Most students are eager to share their Zap It!, Mastery Challenge, or Standardized Test results (Exp). When students move into a new module, they can usually be heard commenting on their success (Pos).

During the last ten minutes of class, the level of student engagement drops. Some students log out of their software early with comments such as “there’s only a few minutes until the bell sounds”. The math teacher or lab facilitator has them log back in and work until the bell sounds. The closer it gets to the end of the class period the more common this practice becomes, but many of the students in each class work until the bell sounds. A few students have to be tapped on the shoulder and asked to pack up and move on to their next class.

The levels of student engagement rise and fall throughout the forty-five minutes of instructional time each day and quantizing of the qualitative observation results indicate that the
majority of the students who participate in the Sharpening Math Skills Lab project work hard and are committed to improving their math skills.

Collective Case Study

This section presents the case studies of two students from each participating grade (six, seven, and eight) that were selected to share their experiences, perceptions, and attitudes toward learning in the Sharpening Math Skills Lab. While the October and January Scantron scores are not considered dependent pre-test and post-test measures, they are pseudo independent as they measure many of the same Grade Level Expectations (GLEs). The students selected for the collective case study showed gains when comparing the October Scantron Achievement Series test and the January Scantron Achievement series test as well as an increase on the Wheatley pretest and posttest of spatial visualization ability scores. The case studies consist of four African American males, one white male, and one white female. Participating students were assigned fictitious names to insure confidentiality of their responses.

Case Study Research

Case study research is defined as research that provides a detailed account and analysis of one or more cases (Johnson & Christensen, 2004). A collective case study or multiple-case data collection strategy was chosen because the researcher wanted to gain greater insight into the attitudes, behaviors, and perceptions of the students working in the Sharpening Math Skills Lab by concurrently studying multiple cases. A researcher is more likely to be able to generalize the results from multiple cases than from a single case (Yin, 1994). Data collection included multiple methods and data sources which included document analysis, tests, observations, and interviews.

A qualitative or depth interview consists of open-ended questions and provides qualitative data about a participant’s thoughts, beliefs, knowledge, reasoning, motivations, and feelings about a topic (Johnson & Christensen, 2004). For these case studies the researcher used
the interview guide approach in which the interviewer enters the interview sessions with a plan to explore specific topics and ask specific open-ended questions of the interviewee (Patton, 1987). These interviews were both conversational and situational as they took place in the windowed office area adjacent to the lab during the school day.

The researcher devised an interview protocol in which the topics and issues covered were specified in advance. The protocol was refined through field testing questions with students in the lab who were not chosen for the case study, discussion with an expert in the field and the peer debriefers. To avoid inadvertently omitting important and salient topics, the interviewer used the same sequencing and wording of questions so that responses would be comparable. Additional questions were asked to prompt the interviewee to fill anticipated gaps in data.

The purpose of data-analysis in qualitative research is to understand the participants’ perspectives and to answer the research questions. Miles and Huberman (1994) advocate the use of data reduction, data display, and conclusion drawing and verification. Data reduction involved selecting, simplifying, and extracting themes and patterns from the observation protocols, field notes, and interview transcripts. Each case was individually examined to organize and attribute meaning to data. A cross-case or thematic analysis for similarities and differences was then conducted. The transcripts were analyzed using Atlas ti software, with coding and sorting of the individual case interview responses into categories of related themes and concepts. The results were then presented in a rich and holistic description of the collective case and its context (Johnson & Christensen, 2004).

Student One: Akeem

Akeem is an African American male in the sixth grade. Considerably shorter than the average middle-school child Akeem stands out with his sparkling brown eyes and bubbly personality. Always cheerful, he is one of the first students in his class to enter the Sharpening
Math Skills Lab and one of the last to leave each day. When Akeem occasionally has to be reminded to return to his seat or to stay on task, he smiles broadly and does as he is asked.

An average math student throughout elementary school, his cumulative records indicate that he was referred for special education testing. The evaluation report from the battery of tests states that he has no learning exceptionality. Akeem scored at the Approaching Basic level on the mathematics portion of the Spring 2007 iLEAP and at the fourth grade level in math on the September Scantron Performance series test. He was selected as a case study because his scores on the WSAT grew 60 percentile points from October (25th percentile) to January (85th percentile) and his scores on the Scantron Achievement Series test grew from 23.3% in October to 63.3% in January, demonstrating a 40 point increase.

Akeem has made more progress using the FASTTMath software than most of his classmates. By midterm, Akeem had been moved to subtraction - the second operations module because he had already mastered the 169 facts in the addition module. His fluency status of facts report for subtraction indicates that he has mastered 66 of the 169 subtraction facts and his retention level is at 86 percent. He is working at the fourth grade level in Larson iSucceed Mathematics at a slower pace, having completed six of the sixteen modules selected for his curriculum with 80% success.

Akeem seemed very pleased and excited when he was asked to be interviewed about his learning experiences in the lab. The interview took place in the researcher’s office adjacent to the Sharpening Math Skills Lab. Akeem, who is normally very talkative, became quiet and soft spoken as soon as the recorder was turned on. He glanced at it nervously a few times, but as the interview proceeded he seemed to forget it was on and became more relaxed.

The interview began with, “How does learning math in the Sharpening Math Skills Lab compare with learning math in your regular math classes?” Akeem stated that participating in
the lab helped him in his regular classes on tests and when he had to do problems that involved multiplication. Elaborating he said, “All my skills in math are better, too.”

When asked what he liked best about working in the Sharpening Math Skills Lab Akeem replied, “FASTTMath and Larson”. With additional questioning to gain more information, Akeem added that he liked FASTTMath because it was fun and he liked Larson iSucceed because he felt he was learning a great deal. A discussion of what he liked best about FASTTMath followed. Akeem enjoys the challenge and the speed of the games. He expressed that “trips” to the FASTTMath Style Gallery were not much incentive stating, “Man, that’s nothing but screen savers.”

Akeem’s least favorite aspect of working in the Sharpening Math Skills Lab is that he has to stop working in FASTTMath to move on to Larson. Speaking somewhat contradictorily he shared that he likes that fact that FASTTMath has a discernable beginning and end each day, but thinks that “Larson goes on and on” referring to the fact that there the lesson structure and pacing of iSucceed software is not contingent upon a specific time frame. Once a new lesson has been mastered the next lesson is begun regardless of the time remaining for the class period.

Akeem’s answer to which program he likes best is embedded in his responses to the previous three questions. He stated that he liked both FASTTMath and Larson equally well, but did admit that if he could choose only one program to work on it would be the Larson iSucceed software.

Akeem feels strongly that the math facts he has learned with FASTTMath have helped with the work in Larson iSucceed Math and in his regular classroom math lessons. Akeem reiterated his statements concerning the reward features of FASTTMath which he volunteered information on earlier in the interview. He enjoys the FASTTMath games, but has not bothered to use the Style Gallery reward features.
Akeem’s comments pertaining to the auditory directions that are provided with the Larson iSucceed software include that he listens to the directions and to the text of the problem usually only once and finds that is enough for him to get the problem. Akeem prefers using one of his teacher’s calculators to the onscreen calculator in the Larson software citing the fact that the other has more features that he can use. Akeem seldom uses the Directions or Listen to the Problem multimedia interfaces, but does use the Review See It option often which gives him a tutorial of how to work a particular type of problem and is available at any time in the problem solving process.

If there was one thing that Akeem could change about the Sharpening Math Skills Lab that would be, “Nothing!” When asked to elaborate he amended his original answer by stating, “Well, we could be in here a little longer.”

Akeem enjoys working with both FASTTMath and Larson iSucceed in the Sharpening Math Skills Lab. He likes the speed of FASTTMath, but does not consider the Style Gallery and games to be motivational. Akeem finds lesson structure and pacing of Larson iSucceed to be little frustrating and only uses one of the available interfaces, but feels his math skills have improved overall through his work in the lab.

Student Two: Shaquille

Shaquille is of both Native American and African American descent and wears his long, curly, honey-colored hair in tightly braided rows or in a pony tail at the nape of his neck. Often referred to the principal’s office in other classes, Shaquille is rarely a discipline problem in the Sharpening Math Skills Lab.

Shaquille’s cumulative records indicate that he attended four elementary schools after repeating first grade and had average math grades during those school years. He was placed in
Shaquille showed a gain of 93 percentile points on the WSAT, moving from the 1st percentile to the 94th percentile in spatial visualization over a period of three months. In the October 2007 to January 2008 interval Shaquille also raised his Scantron Achievement Series Test scores by 46.7 points, starting with 0% percent correct in the October testing session to 46.7% correct in the January 2008 testing session. It was of particular interest to determine if his increased achievement levels were attributed to improved motivation and attitude toward mathematics or to the effectiveness of the Sharpening Math Skills Lab software.

Shaquille has made slow progress in FASTTMath with his fluency of addition facts. By midterm Shaquille had 19 of his 169 addition facts left to master with the program automatically assigning review sessions to provide him with extra practice. Shaquille has also made slow progress in his work with Larson iSucceed math, completing 6 out of the 15 selected learning modules with the mandatory 80% passing rate.

Like many middle school students, Shaquille is very soft spoken during one-to-one conversations with adults, but can be quite loud and boisterous with his peers. On the day of the interview, Shaquille was late for class because he had been in the office for disciplinary reasons. He seemed surprised and said, “Am I in trouble?” when the researcher asked him if he would visit about his work in the lab. It was carefully explained that he was not in trouble and would only be answering questions related to his work in the lab. He seemed relieved and readily agreed to sit in the lab office and talk.

When asked, “How does learning math in the Sharpening Math Skills Lab compare with learning math in your regular math classes?” Shaquille shared that he thought it was harder than the math in his regular class because of the FASTTMath program. Shaquille specified that he
was uncomfortable with the speed at which the math problems flashed on the screen. Although
he plays video games at home, he was not comfortable with the speed of FASTTMath. This
explanation also answered, “What do you like least about working in the Sharpening Math Skills
Lab”. Shaquille was asked again during the interview to verify his answer and reiterated his
earlier statements.

Shaquille shared that using the Larson iSucceed software is what he liked best about the
Sharpening Math Skills Lab. Probing a little deeper, he explained that he liked the step-by-step
problem solving features of iSucceed software and the fact that he could work at his own pace
using the software. Shaquille talked about how the iSucceed software presents him with a new
problem and then breaks it into manageable steps making it easier for him to understand. He
also stated that “Larson was helping me with my multiplication and division skills.” The next
question in the interview protocol asked which software program Shaquille preferred using in the
lab and why. This answer was embedded in his response to what he liked best about working in
the Sharpening Math Skills Lab when he talked about how much he enjoyed using Larson
iSucceed software, but was asked the question during the interview with the idea that he would
elaborate, but he did not add any additional information.

Shaquille stated that he felt that the math facts he was learning in the Sharpening Math
Skills Lab were helping in his regular math class. The reward features of FASTTMath were
enjoyable to Shaquille. He mentioned that he had to master around seventy math facts before he
was allowed to choose from one of the six reward games of which Rocketman was his favorite.
In a member checking session about one week after the original interview, Shaquille shared that
although he enjoyed playing Rocketman, it was not enough incentive to want to learn the seventy
math facts he had to learn before he could choose a game. He stated that he had mastered the
facts because he became tired of having to repeat the same facts each day.
When questioned relating to one of the specific multimedia features of the Larson iSucceed software that involves listening to the problem to help him solve it, Shaquille said that it helped to hear the directions and the problem before he began working on it because it helped him to understand what he had to do in order to solve the problem. Shaquille listens to a problem sometimes twice in order to solve the problem. At this point the researcher asked Shaquille how he felt about the sounds in the FASTTMath program, particularly the sound effects employed during the speed drills and games. Shaquille shared that he found those noises distracting and that is why he often prefers to use FASTTMath without his headset or with the headset on and the volume turned off so as not to draw the attention of his teacher in the lab.

The only feature of the Larson iSucceed program that Shaquille said he found helpful was the online calculator. He shared that he did not use the glossary feature or the Review See It problem solving tutorial feature. When asked what he would do if he could change anything about the lab that he wanted to, Shaquille stated, “I would like for FASTTMath to slow down!”

Shaquille enjoys participating in the Sharpening Math Skills Lab, but does not enjoy FASTTMath as much as Akeem, the other sixth grade student, does. He finds the speed and extraneous noises of FASTTMath to be frustrating. Unlike Akeem, Shaquille does not use the Review See It! feature, but does use the repeated directions feature.

Student Three: Ian

Ian is a gentle giant of Acadian French descent with neatly combed straight brown hair. He is a kind young man who speaks in a soft nasal monotone and is very methodical in his speech and mannerisms. Ian was placed in a public school non-category preschool program at age three. In grades one and two, he was in a self-contained classroom for learning disabled, but was placed in mainstream classes with learning disabled special education services in third grade.
His math grades indicate he is above average, but Ian scored at the Approaching Basic level on the Spring 2007 iLEAP and scored at the fifth grade level on the September 2007 Scantron Performance Series test. Ian was selected as a case study participant because of a 40 percentile point jump in his WSAT scores from scoring at the 44th percentile in October 2007 to the 84th percentile in January 2008. His growth during the same interval on the Scantron Achievement Series test was 6.6 points, moving from 26.70 % correct to 33.30 % correct.

Ian has made slow progress in developing automaticity of addition facts, which is the first assigned operation module in FASTTMath, but is close to mastering all 169 facts and moving on to subtraction. He works in a modified fifth grade level in Larson iSucceed math and has successfully completed with minimum passing score of 80%, six out of the eleven assigned learning modules for his specifically designed curriculum.

As with the other participants in the collective case study, the interview took place in the small office adjacent to the Sharpening Math Skills Lab during the school day. Ian seemed surprised that he had been selected to be a part of the researcher’s study, but readily agreed to the interview. Ian seemed uncomfortable with the recorder and at first his speech was perceptibly different from his usual conversational style. When asked how learning in the Sharpening Math Skills Lab compared with learning in his regular math class, Ian repeated the question in the form of a statement and added that learning was exactly the same in both classes. Redirecting with additional questions did not yield a different answer.

Ian seemed to brighten up when asked what he liked best about working in the Sharpening Math Skills Lab. Ian mentioned that he wanted to be a video game designer “when he grows up” and he feels that the geometry lessons he receives in the Sharpening Math Skills Lab will be beneficial to him.
When asked what he liked least about working in the Sharpening Math Skills Lab, Ian became animated. He said, “When I work with Algebra it is too hard and I don’t even know what a variable is. Another thing is when I work with division I don’t even know that and then I just don’t get it.” Encouraged by this burst of sharing, the researcher asked, “What happens in the lab when you are working on something and you don’t understand a question?” Ian replied, “If I don’t ask for help, I just choose an answer and I get it wrong and wind up getting zero out of the number of questions correct… and then I have to retake the test.”

When asked, “Which program do you like working with best in the Sharpening Math Skills Lab and why?” Ian sounding more relaxed replied, “FASTTMath because when I do my math facts I do it real fast and it gets easy.” This response segued easily into the next question which asks, “Do you feel that the math facts you have learned with FASTTMath have helped you with your work in Larson iSucceed Math and your regular classroom math lessons?” Ian was thoughtful for a moment before responding positively on his improved grades in math. Ian also commented positively about the reward features of FASTTMath. When asked to elaborate on the features of the reward games of FASTTMath, Ian mentioned that the sound effects added to the games made them more enjoyable to him.

Moving on to the questions that relate specifically to the Larson iSucceed software, Ian shared that when he uses Larson iSucceed software, listening to the problem is very helpful and that he has listened to a problem five or six times in order to solve it and uses the Review See It feature to get help with problem solving.

Ian uses the glossary occasionally and uses the calculator for almost everything stating, “I use the calculator a lot on easy things like multiplication, subtracting and addition”. If he could change one thing in the Sharpening Math Skills Lab he would create a sequel to FASTTMath to work on geometry skills and call it FASTTMath: Geometry Style.
Like Akeem, Ian enjoys both FASTTMath and Larson iSucceed. He feels that his overall math skills have improved even though like the other students in the collective case study, Ian has experienced frustration with some aspects of multimedia instruction. Ian finds most of the software program interfaces to be beneficial and remains positive about learning math in the Sharpening Math Skills Lab.

Student Four: Sabrina

Sabrina, a white female of Acadian French descent is a seventh-grader with curly, flaming red hair which is usually unkempt. Sabrina is very quiet and seldom asks for assistance. She works steadily each day on her computer tasks with brows furrowed in concentration. Her cumulative records indicate that she moved to southwest Louisiana in her fifth grade year from a medium-sized city on the Gulf Coast in south Louisiana.

Attending four elementary schools before enrolling in Middle School One, she scored at the third grade level on the September 2007 Scantron Performance Series and the extreme low end of the Unsatisfactory range on the Spring 2007 iLEAP. Selected as a case study on the basis of showing more improvements in both spatial visualization and academic achievement than the other females during the October 2007 to January 2008 interval, Sabrina gained 22 percentile points on the WSAT and had a 6.7 point increase on the Scantron Achievement Series tests. Sabrina scored at the 3rd percentile on the WSAT in October 2007 and at the 25th percentile in January 2008. She scored 23.30% correct on the Scantron Achievement Series test in October 2007 and 30% correct in January 2008.

Sabrina is still working in the addition module in FASTTMath with 137 of the 169 math facts mastered. She is working in a modified fifth grade level Larson iSucceed curriculum and has completed only two of the assigned eleven learning modules with 80% accuracy.
Sabrina’s interview took place in the office adjacent to the lab. She was very reluctant to provide the researcher with in depth responses which resulted in rephrasing or redirecting questions during the interview. When asked how she felt learning in the Sharpening Math Skills Lab compared with learning in her regular math classes, Sabrina replied that she did not understand what that question meant. The researcher offered an explanation and Sabrina shared that she liked working in the lab much better than working in her regular math class. Her favorite thing about coming to the lab is FASTTMath because she finds visits to the Style Gallery to be fun and the reward games both fun and challenging. When asked what she liked least or disliked about coming to the lab, Sabrina replied, “I don’t have no worse part.”

Sabrina’s reply to which program did she like best was covered in her response to an earlier question.

Sabrina feels that the addition facts she has mastered in FASTTMath have helped her in both Larson iSucceed math and in her regular math class. She also feels that working in the iSucceed software has helped her improve in her regular math class. She mentioned earlier in the interview how much she enjoyed the reward features of FASTTMath, so an additional question was asked to confirm her original response.

Listening to both the directions and to the problem is helpful to Sabrina. She usually listens to the directions or to the problem twice if she does not get it the first time. Sabrina uses the online calculator and the Review See It feature frequently, but has never used the glossary. When asked what she would change about the Sharpening Math Skills Lab, Sabrina suggested adding another program for students to use.

Sabrina echoed the comments made by the other collective case study participants when she shared that she felt her overall math skills were improving based upon her work in the Sharpening Math Skills Lab. As the only female in the collective case study, it was interesting to
note that she was the only student who expressed enthusiasm for the reward visits to the
FASTTMath Style Gallery.

Student Five: Dashonte

Dashonte, an African American eighth grade male, stands six feet, two inches tall and is
an outstanding basketball player on the school team. He wears his hair tightly braided in rows
with the ends neatly gathered into a ball at the nape of his neck. Dashonte’s cumulative records
indicate that he attended three elementary schools and was designated as a “504” student in need
of classroom learning modifications in elementary grades. He was evaluated for special
education services and placed in learning disabled class at Middle School One.

Dashonte attends class in the Sharpening Math Skills Lab because he scored in the
Approaching Basic range on the Spring 2007 iLEAP. He also scored at the fourth grade level on
the Scantron Performance Series September 2007 test. Dashonte showed a growth of 29 points
on the Scantron Achievement Series test, moving up from 12.9% correct in October 2007 to
41.9% correct in January 2008. His gain on the WSAT was 21 percentile points, moving from
the 55th percentile in October 2007 to the 76 percentile in January 2008.

Dashonte has made slow progress mastering 142 of the 169 fluency math facts in the
addition module of FASTTMath by midterm. Dashonte has also made slow progress working in
the modified fourth grade curriculum, with only three of the assigned sixteen modules completed
with 80% success.

Dashonte feels that the math problems he does in the Sharpening Math Skills Lab are
easier than the math problems he does in his regular classroom. He feels that the best part about
the lab is that it is more fun than regular math. Dashonte does not like Larson math because
there are no games to play. To clarify his response, the researcher asked if he was referring only
to FASTTMath when he talked about the math lab being more fun than his regular classes.
Dashonte responded with a “Yes Ma’am”. When asked about his favorite program in the lab, Dashonte began talking about his progress in FASTTMath. He is still in the addition module, but is proud of the fact that he has mastered enough facts to play the reward games. Dashonte feels that his work in FASTTMath has helped him with his math lessons in Larson iSucceed and in the regular classroom and that the reward features of FASTTMath motivate him to work harder in learning his facts.

When asked about listening to problems in Larson iSucceed to help improve the student’s ability to solve the problem, Dashonte sheepishly admitted that he did not like using the headphones in the lab, but that he would listen to a problem sometimes up to three times before solving it. He uses the online calculator and the Review See It feature frequently, but has never used the glossary.

If Dashonte could change one thing about the Sharpening Math Skills Lab it would be, “to not use Larson as much”.

Dashonte, like Shaquille, does not like to use the headsets in the computer lab. He does however, make good use of the repeated directions and the Review See It feature. Like the other students in the case study Dashonte feels that the math fact skills he is learning the Sharpening Math Skills Lab helps with his regular mathematics instruction.

Student Six: Kenneth

Kenneth is an eighth grade African American male of medium height and build with short black curly hair. He wears glasses and is a quiet, hard working student. He attended the same elementary school for Kindergarten through fifth grade. Kenneth’s case is of particular interest because he completed an entire grade level in Larson iSucceed mathematics within three months.
Kenneth was also selected as a case study because he scored at the 98th and 97th percentiles respectively, on the October 2007 and January 2008 WSAT sessions. Kenneth scores were at the fifth grade level on the Scantron Performance Series test in September 2007 and at the upper end of the Approaching Basic scale on the Spring 2007 iLEAP. His Scantron Performance Series Achievement test scores reveal a 9.6 point increase from 45.2% correct in October 2007 to 54.8% correct in January 2008.

Kenneth is currently working on subtraction, the second operations module in FASTTMath and has mastered 58 of the 169 fluency facts. Kenneth is very proud of the fact that he was the first Sharpening Math Skills Lab student to finish an entire grade level curriculum with 80% accuracy and be moved up to another grade level. At midterm, Kenneth has completed five out of the sixteen assigned modules in his new curriculum.

Kenneth was very excited when the researcher asked him for an interview about his learning experiences in the lab. He looks forward to coming to the lab every day and when asked how this compares to learning in his regular math class shared that his level of enjoyment for regular math was “not so much”.

Kenneth’s favorite aspect of the Sharpening Math Skills Lab is that he “gets to do math”. His least favorite aspect was that he still struggles with division. Kenneth likes the way division lessons and problems are presented in the iSucceed software, but feels he needs more practice.

When asked about the program he liked best in the Sharpening Math Skills Lab and why, Kenneth shared that he preferred iSucceed because it is untimed. He finds the speed of the FASTTMath automaticity drills to be very frustrating. When asked, “Do you feel that the math facts you have learned with FASTTMath have helped you with your work in Larson iSucceed Math and your regular classroom math lessons?”, Kenneth was thoughtful for a moment before replying. Although he doesn’t care for the FASTTMath program as much as the iSucceed
program, Kenneth feels that his ability to do addition problems has improved. He likes playing the games in FASTTMath, but doesn’t consider them to be motivational when learning his facts.

In using the Larson iSucceed software, Kenneth listens to the directions and the math problem only once before solving. He feels that listening to the problem is beneficial, but does not recall ever having to repeat the directions or use the Review See It feature. Kenneth relies heavily on the online calculator and the glossary features. If he could change one thing in the Sharpening Math Skills Lab it would be to get rid of FASTTMath completely and spend more time working in the Larson iSucceed program.

While Kenneth does not use the repeated directions feature as often as Dashonte, he does agree that the feature is useful. Kenneth’s views of FASTTMath are similar to Shaquille’s in that he would prefer to spend more time working with the Larson iSucceed software. Kenneth is the only student who considered the glossary to be an indispensable aide.

Thematic Analysis of Case Studies

The collective case study addresses student attitudes and behaviors as they work in the Sharpening Math Skills Lab and their perceptions of the principles of instructional design utilized in the program interfaces of the lab software. For the purposes of this cross case analysis, information gathered on student background and achievement are included. The ten observation protocol questions are grouped by attitude, motivation, and instructional design principles.

Student Background

The collective case study participants are comprised one female and five males: Sabrina, a white female of Acadian French descent; Akeem, Dashonte, and Kenneth, African American males; Ian, a white male of Acadian French descent; and Shaquille, a male of Native American and African American descent. Three of the students attended multiple elementary schools before enrolling in Middle School One (Shaquille, 4 schools; Sabrina, 4 schools; and Dashonte, 3
Akeem, Ian, and Kenneth attended one elementary school. Shaquille repeated a grade in elementary school. Ian was classified as a special education student during elementary school, while Dashonte was identified as special education during middle school.

**Student Achievement**

The most common characteristic shared by these students is poor academic performance in mathematics. All of these students are functioning at least two grade levels below their current grade placement and are considered “at risk” of failing the LEAP test in 8th grade because of poor performance on the iLEAP. Akeem, Ian, Dashonte, and Kenneth scored at the Approaching Basic Level while Shaquille and Sabrina scored in the Unsatisfactory range on the Spring 2007 iLEAP.

**Table 5.2  Collective Case Study Scantron and WSAT Scores**

<table>
<thead>
<tr>
<th>Student</th>
<th>Grade</th>
<th>October Scantron % Correct</th>
<th>January Scantron % Correct</th>
<th>Change</th>
<th>October WSAT NPR</th>
<th>January WSAT NPR</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akeem</td>
<td>6</td>
<td>23.30%</td>
<td>63.30%</td>
<td>40</td>
<td>25th</td>
<td>85th</td>
<td>60</td>
</tr>
<tr>
<td>Shaquille</td>
<td>6</td>
<td>0%</td>
<td>46.70%</td>
<td>46.7</td>
<td>1st</td>
<td>94th</td>
<td>93</td>
</tr>
<tr>
<td>Ian</td>
<td>7</td>
<td>26.70%</td>
<td>33.30%</td>
<td>6.6</td>
<td>44th</td>
<td>84th</td>
<td>40</td>
</tr>
<tr>
<td>Sabrina</td>
<td>7</td>
<td>23.30%</td>
<td>30%</td>
<td>6.7</td>
<td>3rd</td>
<td>25th</td>
<td>22</td>
</tr>
<tr>
<td>Dashonte</td>
<td>8</td>
<td>12.90%</td>
<td>41.90%</td>
<td>29</td>
<td>55th</td>
<td>76th</td>
<td>21</td>
</tr>
<tr>
<td>Kenneth</td>
<td>8</td>
<td>45.20%</td>
<td>54.80%</td>
<td>9.6</td>
<td>98th</td>
<td>97th</td>
<td>-1</td>
</tr>
</tbody>
</table>

The collective case study participants were chosen based on their gains on both the Scantron Achievement Tests and Wheatley Spatial Ability Test over a period of three months. Table 5.2 displays case study participants’ Scantron Achievement and WSAT scores. Although these students made moderate to significant gains on their Scantron Achievement Tests, the highest score among the group is Akeem’s 63.3% correct, which is still considered to be a failing
grade. The greatest gains occur in the difference between the October and January WSAT tests. With the exception of Sabrina’s 25th percentile scores, the remaining students demonstrated spatial visualization skills in the upper range of the national percentile ranking on the January test.

Collective Case Study Findings

The Collective Case Study findings on student attitudes, student motivation, and student perceptions of instructional design features are included in this section.

Student Attitudes

All students shared that they enjoyed working in the Sharpening Math Skills Lab and that the skills they learned through use of the software helped them improve in their regular math classes. Their opinions varied on each of the software programs. Akeem and Sabrina expressed a great deal of enjoyment for FASTTMath. Ian and Dashonte also like FASTTMath, but Shaquille and Kenneth find the speed of the game to be very frustrating. Only one student, Dashonte, expressed a dislike of the Larson iSucceed software. The remaining students were positive about the program, although Akeem thought Larson iSucceed tended to go “on and on”. Kenneth was most enthusiastic about the program as evidenced by his success.

Table 5.3, Table 5.4, and Table 5.5 represent the collective case study results for the Attitude Toward Math Inventory (ATMI) Subscales of Self-confidence, Value, and Enjoyment. This quantitative data was included with the multi-case study because it provides important information on the case study participants’ attitudes toward math. The total ATMI results for the six case study students reveal that they have a positive attitude toward math. A comparison of these totals with the entire experimental group totals show that the case study participants have more self-confidence, valuation, and enjoyment of mathematics than their Sharpening Math Skills Lab peers.
Table 5.3  Collective Case Study ATMI Self-confidence Subscales Frequencies

<table>
<thead>
<tr>
<th>ATMI Self-confidence Subscales Frequencies (n=6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Item 9*</td>
</tr>
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<td>Item 10*</td>
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<tr>
<td>Item 11*</td>
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<td>Item 13*</td>
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<td>Item 14*</td>
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<tr>
<td>Item 22</td>
</tr>
<tr>
<td>Item 40</td>
</tr>
<tr>
<td>Totals</td>
</tr>
<tr>
<td>Percent</td>
</tr>
</tbody>
</table>

Note: * Indicates corrected values of reversed inventory items.

Student Motivation

When asked about the motivational aspects of the reward games and the Style Gallery features of FASTTMath, the case study participants had a range of opinions. They all shared that they enjoyed playing the FASTTMath reward games, but had varying opinions on whether they felt the games encouraged them to work harder to learn more facts. Both Kenneth and Shaquille mentioned earlier in the interview that they did not like FASTTMath. Although they did claim to enjoy playing the games, they did not feel they were motivational. Akeem, Sabrina, Ian, and Dashonte were enthusiastic about the FASTTMath reward games. Sabrina and Akeem were the only two to express strong opinions about the Style Gallery. Sabrina enjoys being able to select new colors and designs for her FASTTMath screen, while Akeem feels it is useless stating, “Man, that’s nothing but screensavers.”
Table 5.4  Collective Case Study ATMI Value Subscales Frequencies

<table>
<thead>
<tr>
<th>ATMI Value Subscales</th>
<th>Frequencies (n=6)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
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<td>10%</td>
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Table 5.5  Collective Case Study ATMI Enjoyment Subscales Frequencies

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<th>Frequencies (n=6)</th>
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<td>8.30%</td>
<td>20%</td>
<td>38.30%</td>
<td>25%</td>
</tr>
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</table>

Note: * Indicates corrected values of reversed inventory items.

Table 5.6 represents the quantitative results for the ATMI Motivation Subscale

Frequencies which reveal that the case study participants are highly motivated. A comparison of
case study totals with the whole experimental group indicates that the case study participants are more motivated than their peers in the Sharpening Math Skills Lab.

Table 5.6  Collective Case Study ATMI Motivation Subscales Frequencies

<table>
<thead>
<tr>
<th>ATMI Motivation Subscales</th>
<th>Frequencies (n=6)</th>
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<tr>
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<td>Item 34</td>
<td>2</td>
</tr>
<tr>
<td>Totals</td>
<td>3</td>
</tr>
</tbody>
</table>

Percent 10% 3.30% 16.70% 53.30% 16.70%

Note: * Indicates corrected values of reversed inventory items.

Student Perceptions of Instructional Design Features

Math-delayed students often have limited meta-cognitive abilities (Mercer, 1997) and this was demonstrated among the Sharpening Math Skills Lab students as the researcher began to field-test the case study interview protocol questions that related to the principles of instructional design. The researcher used the Principles of Instructional Design Observation Protocol (PIDOP) to observe the students interacting with program interfaces and began devising interview questions based on this instrument. It became evident fairly quickly that these students did not have the comprehension and meta-cognitive abilities to conduct an in-depth analysis of their own learning as it relates to text, narration, and graphics so a new tactic had to be developed.

During observations using the PIDOP, case study students were asked to comment on the sound effects present during the FASTTMath reward games which relate to the coherence and split attention principles. Shaquille was the only student who found them to be a distraction and he often turned off his headset while playing. Ian feels that the sound effects enhance his
enjoyment of the game. The remaining students didn’t feel that the sound effects had any effect on them.

Akeem was the only student who did not care for using the online calculator. He preferred a handheld model because it had more features than the “Larson calculator”. The students commented favorably on their ability to change the size and shape of the calculator and its location on the screen.

The Review See It feature provides students with an online tutorial in the Larson iSucceed math software and can be accessed at any time during problem solving. Akeem, Ian, Sabrina, and Dashonte use the feature frequently for assistance, but Shaquille and Kenneth do not. Ian and Kenneth were the only students to share that they used the online glossary in the Larson iSucceed software. Ian uses it occasionally, while Kenneth stated that he used it often.

In addition to the interaction with the students in the lab while conducting observations with the PIDOP, the researcher interviewed the students on the specific features of the programs they used in terms of their helpfulness: narration of directions and problem text, the Review See It, calculator, and glossary. Most of the students find listening to the directions and to the problem helpful regardless of whether the text is present on screen. This relates to the split attention, modality, and redundancy principles. Akeem was the only student who did not like to use the auditory features of the programs because he did not find them helpful. Students varied on the number of repetitions before the directions or the problem was understood. Kenneth usually gets it the first time, while Ian sometimes listens 5 or 6 times before he feels confident about a problem. Shaquille and Sabrina listen up to two times, while Dashonte shared that he sometimes needs to listen a third time to fully understand the directions and/or the problem.
Summary

Data collection on the collective case study participants’ backgrounds, achievement levels, attitudes, motivation, and perceptions of the effectiveness of software interfaces revealed a number of common characteristics. These math-delayed students began experiencing difficulties in learning at an early age and for the most part managed to be promoted from one grade level to the next without mastering math facts or adequate problem solving skills. The Sharpening Math Skills Lab case study students value mathematics and are more confident in their mathematical abilities than their math-delayed peers which is evidenced by greater success in mathematics achievement and spatial visualization.

While their selection and usage of the software interfaces varies with their personal learning styles and needs, students found the repeated directions and Review See It features to be particularly useful. These design features relate to the coherence, modality, and split attention principles of instructional design which were found to be embedded throughout the interfaces of both FASTTMath and Larson iSucceed software.

In summary, the students in the collective case study have all experienced frustration with different aspects of working in the Sharpening Math Skills Lab, but readily agree that the activities are motivational and are improving their math fact fluency and problem solving skills.
CHAPTER SIX
DISCUSSION AND CONCLUSIONS

Chapter six discusses the results of the quantitative and qualitative research conducted in this study to determine if the Sharpening Math Skills Lab technology-mediated mathematics instructional practices for math-delayed middle school students have positive effects on their mathematics achievement, spatial visualization ability, engagement in learning, attitudes toward mathematics instruction, and perceptions of the effectiveness of multimedia design interfaces. This chapter will compare and contrast the results of this study with previous studies to substantiate and/or challenge findings and to explore the variables examined in the study to determine relationships. Limitations of the study and recommendations for the practice of multimedia mathematics instruction, the Sharpening Math Skills Lab program implementation, and future studies are also included in this chapter.

Findings

The quantitative and qualitative study findings that relate to the research questions on student achievement, spatial visualization, student attitudes and behaviors, and implementation of multimedia principles are listed below and discussed in detail later in this chapter.

The findings are:

- No statistically significant difference was found in mathematics achievement between control and experimental groups.

- The measurement of the spatial visualization abilities of the Sharpening Math Skills Lab students revealed a tremendous growth in student spatial visualization.

- A small positive correlation was found between spatial visualization skills and mathematics achievement in the Sharpening Math Skills Lab students.
Most students in the Sharpening Math Skills Lab value and enjoy mathematics but lack confidence in their abilities to succeed in mathematics.

Students in the Sharpening Math Skills Lab revealed a high level of student engagement throughout most of the daily class periods.

**Student Achievement Discussion**

The results of the research comparing the experimental and control group mathematics achievement were not in keeping with the majority of the findings in the literature review. In a number of mathematics Computer Assisted Instruction (CAI) software programs examined in best evidence synthesis (Slavin & Lake, 2006) and meta-analysis (Slavin, Lake, & Groff, 2007) small positive effect sizes were found. It was reasonably expected based on these results which were reported in Chapter Two that the students participating in the Sharpening Math Skills Lab would have at least demonstrated greater academic achievement growth than their control group counterparts who do not receive technology mediated services. Instead of the expected small positive effect size, no significant difference was found between the two groups.

**Extraneous Variables**

There are a number of extraneous factors which can be explored to determine why the Sharpening Math Skills Lab math-delayed students did not perform better than the control group students. These include program implementation, quality of the software programs utilized, length and quality of regular mathematics instruction, teacher qualifications, and student attitudes and motivation toward learning. Each of these are discussed below.

**Program Implementation**

The careful explanation of program implementation differentiates this study from most of the studies reported in Chapter Two. Many of the CAI studies included in the literature review are missing important details such as instructional time, student characteristics, teacher
qualifications, and the quality of regular mathematics instruction. This study includes information on program features such as curriculum development and the amount of time students spend in regular math classes and using CAI. Another characteristic of this study that sets it apart from other studies is the evaluation of the software used in the Sharpening Math Skills Lab based on the principles of instructional design.

Quality of Software Programs

In addition to comparing the academic achievement of the math-delayed experimental and control groups, a determination of quality of FASTTMath and Larson iSucceed software for the purposes of this study was made based on the results of the Principles of Instructional Design Observation Protocol (PIDOP) which were reported in Chapter Three. Both programs reflect correct implementation of most of the principles of instructional design (Moreno & Mayer, 2000) and have interface features such as repeated directions and review modules that the collective case study participants found useful.

In FASTTMath, the instructional sequences exhibited correct application of principles of instructional design. These are the spatial contiguity, temporal contiguity, redundancy, split attention, and modality principles. However, the coherence principle of instructional design was violated by the presence of extraneous sound effects throughout the FASTTMath program.

This researcher noted the web-based Larson iSucceed software demonstrated strength in the spatial contiguity, temporal contiguity, and coherence principles; however, the split attention, modality, and redundancy principles were inconsistently applied in the software interfaces. In many lesson or assessment sequences of FASTTMath and Larson iSucceed, students were provided with the option of selective use of the features in which the split attention, modality, and redundancy principles of instructional design were employed. This is significant because intermittent usage of the interfaces in which these three principles are inconsistently applied
reduces potential negative learning effects. Additionally, allowing students the opportunity to select these interfaces on an “as needed” basis enables them to address their own learning styles and preferences.

**Length and Quality of Regular Instruction**

The length and quality of regular mathematics instruction are other factors which may have influenced the student achievement outcomes. The experimental group students receive 45 minutes per day of technology-mediated mathematics instruction and 45 minutes per day of regular mathematics instruction. Students in the control group schools receive 90 minutes per day of regular mathematics instruction.

The teacher’s choice of curriculum materials is an extraneous variable that influences the quality of regular instruction. While the use of the Louisiana Comprehensive Curriculum is encouraged in all three middle schools, teachers have autonomy to select other activities or use traditional textbook based instructional practices.

**Teacher Qualifications**

The quality of the math instruction may be another contributing factor. Teacher quality is as strongly related to student academic performance as student background characteristics (Wenglinsky, 2002). Teacher effectiveness may vary from classroom to classroom within the same school and within the same school district (Sparks, 2003). Traditional teacher qualifications such as the number of years of experience and degrees, and other factors such as dedication and work ethic, classroom management, parent satisfaction, positive relationship with administrators, and ability to improve math achievement should also be considered in evaluating teacher effectiveness (Jacobs & Lefgren, 2006).
Summary of Student Achievement

Although costly to implement, it is highly unlikely that Computer Assisted Instruction will lose footing in the educational setting based on the results of this research or research projects such as those featured in the literature review as the use of technology is too firmly embedded in workplace and social environments. The fact that no difference in academic achievement was found between control and experimental groups should not cast a pall on the use of multimedia instruction, but does create the need for further research and careful examination of the extraneous variables and the Sharpening Math Skills program in terms of best uses of fiscal and personnel resources.

Spatial Visualization Discussion

Spatial Visualization Ability

The measurement of the spatial visualization abilities of the experimental group revealed a tremendous growth in student spatial visualization in the three months between the Wheatley Spatial Ability Test (WSAT) pretest and posttest. This significance level (.000, p < 0.05) may be attributed to a combination of several factors: the testing threat to internal validity, the principles of instructional design utilized in the software interfaces, or a change in student attitude and motivation toward producing quality work.

The testing threat to internal validity refers to the effect that the second administration of a test may have on students’ scores as a result of previously having taken the test. In other words, the experience of having taken a pretest may alter the results obtained on the posttest independent of any treatment effect or experimental manipulation intervening between the pretest and the posttest (Johnson & Christensen, 2004). The testing threat poses the possibility that exposure to and practice of the type of spatial visualization problem solving on the WSAT pretest partially explains the significantly improved performance on the WSAT posttest.
Another possible explanation for the spatial visualization pretest - posttest results lies in the principles of instructional design used in the software interfaces of the multimedia programs featured in the Sharpening Math Skills Lab. The spatial environments created through interaction with the software provide students with the opportunity to increase spatial visualization skills. The relationship between spatial ability and mathematical ability is based upon the fact that operations performed while interacting with mental models in mathematics are often the same as those used to operate in spatial environments (Battista, 1994). Adding credence to this explanation is the fact that, as mentioned previously in this chapter, the spatial contiguity, split attention, and modality principles which relate to spatial visualization were strongly evidenced in FASTTMath and in many Larson iSucceed interfaces.

Spatial Visualization and Student Achievement Correlation

A small positive correlation between student spatial visualization ability and mathematics achievement was found. The relationship was further explained by linear regression analysis which revealed that a student’s mathematics achievement scores accounted for a small percentage of variation in their spatial visualization skills. Spatial visualization has been theoretically tied to mathematics achievement because a visual image not only organizes the data at hand in meaningful structures, but is also an important factor guiding the analytical development of a solution (Fischbein, 1987). The statistical results of this study add to the growing body of evidence on the relationship between spatial visualization and mathematical achievement.

While the correlation and linear aggression statistical procedures results are not strong enough to completely validate Wheatley’s (1991) theory that spatial visualization is linked to mathematical problem solving ability, anecdotal evidence presented in the collective case study lends support to this idea. For example, Kenneth’s national percentile scores were 98 (pretest)
and 97 (posttest) and he successfully finished an entire grade level and a half of another one of Larson Intermediate iSucceed Math by midterm. While Kenneth has consistently performed below grade level and poorly on the LEAP and iLEAP tests throughout his school years, his success in the lab problem solving activities illustrate one of Wheatley’s (1991) assertions about spatial visualization ability and mathematics achievement. Wheatley stated that students with high spatial ability whose performance was average or below on standardized mathematics tests and in school mathematics class had an excellent grasp of mathematical ideas and were able to solve non-routine problems, often creatively.

Student Characteristics Discussion

The results of Attitude Toward Mathematics Inventory (ATMI) and collective case study interviews reveal that the Sharpening Math Skills Lab students express opinions that identify them as having similar characteristics to math-delayed students described in the literature review; however, observation of students in the Sharpening Math Skills Lab revealed a high level of student engagement throughout most of the daily class periods.

Student Attitudes

The attitudes toward and behaviors in mathematics learning expressed by the math-delayed students in the experimental group were similar to those found in the literature review. The Sharpening Math Skills Lab students struggle with motivational (Middleton & Spanias, 1999; Kroesbergen, 2002), meta-cognitive (Goldman, 1989; Mercer, 1997), memory (Hasselbring & Goin, 2005), and self-efficacy issues (Covington, 1992; Dweck, 2000). The only area in which they differed was in the high level of student engagement (Covington, 1992) observed during the Sharpening Math Skills Lab sessions.
Levels of Student Engagement

The problem solving activities in the Sharpening Math Skills Lab provides math-delayed students with opportunities to work on skill level appropriate problem solving skills at their own pace which results in a high level of student engagement and enhanced self-efficacy. This is especially beneficial because offering students a series of relatively easy tasks can lead to a false sense of self-efficacy and this practice is at odds with the intent to give students access to challenging mathematics, as noted by Kroesbergen (2002).

Information gathered during classroom observations and the collective case study interviews reveal that this level of engagement is the result of student enjoyment of the software programs and improved feelings of self-confidence brought about by successfully solving math problems. As documented on the LaSOP, students ask questions, offer help to peers, express feelings of satisfaction, and discuss their learning activities with their teacher and the lab facilitator.

This higher than expected level of student engagement may be explained by the program implementation components and design features of the lab software. Each lab student is working in an individually designed Larson iSucceed curriculum based on the results of their Scantron Performance Series test. For the first time in many years, students are being challenged on a level in which they can succeed. Research indicates that achieving a balance between sufficient opportunities for success and tasks that require considerable effort requires carefully designed curricular materials and instructional practices (Woodward, 1999).

Recommendations for Practice

The implications and recommendations for the practice of multimedia instruction and the Sharpening Math Skills Lab program implementation based on the research findings and conclusions of this study are included in this section. The primary recommendations discussed
in this section focus on (1) improving software interface design to enhance cognitive growth and (2) strengthening the relationship between the activities in the Sharpening Math Skills Lab and the regular classroom mathematics content.

Multimedia Instruction

The recommendations for multimedia based on the results of this study are two-fold. First, designers need to pay greater attention to cognitive processes such as spatial visualization in the creation of software programs. Second, instructors should purchase software that best addresses cognitive functions instead of looking solely on program content or at novelty features. It's not the technology that creates learning, it's what we do with it (Mayer, 1997). The literature review in Chapter Two reports the effect on academic of learning with multimedia, focusing especially on mathematics programs. Relatively few of the studies reviewed delve into the specific qualities of program implementation and characteristics of media interfaces that promote or accelerate cognitive growth. Studies of CAI are best explored from a cognitive psychology perspective. This will enable instructional designers and practitioners to develop multimedia products that, when combined with other factors such as quality instructors, will produce academic achievement gains over traditional instruction.

One of the cognitive functions that should be addressed by multimedia, especially in remedial mathematics instruction is spatial visualization due to the link between mathematical problem solving ability and spatial visualization (Brown & Wheatley, 1989, 1997) in math-delayed students. The work of Mayer, and others, provides an example of well-grounded multimedia research that is yielding interesting and robust findings (Doolittle, 2001) and should be continued.

What has been learned from this study about the principles of instructional design has numerous implications on the practice of multimedia instruction. In addition to evaluating
software programs for accuracy of content, appeal of presentation, and ease of usage, this researcher recommends that developers and technology program coordinators should pay attention to how the six principles of instructional design – split attention, coherence, redundancy, modality, spatial contiguity, and temporal contiguity are implemented. This recommendation is supported by the work of Moreno and Mayer (2000) and Harp and Mayer (1998) who feel that improperly implemented multimedia features can actually detract from the learning process, particularly if they are introduced as an effort to capture students' attention.

Research has shown that adding “toots and whistles” aimed at heightening student interest with entertaining details interfere with learning and promotes recall of inappropriate knowledge (Garner & Brown, 1992; Harp & Mayer, 1998). When using multimedia that has been developed without attention paid to proper implementation of instructional design principles, Harp and Mayer (1998) suggest a delay of presentation of multimedia until after the introduction of the topic or instruction information to allow students to adequately process that which is important. The findings of this study are also supported by the findings of Mayer and Sims (1994) and Mayer (1997) that software should be evaluated for the proper synchronization of verbal and visual materials which allow students to encode subject materials in more than one manner, thereby increasing possible mental connections.

Sharpening Math Skills Lab

The findings of this research study contribute to the body of research on mathematics CAI, and provide information that could be used to shape learning in the Sharpening Math Skills Lab. With No Child Left Behind (NCLB) mandated assessments of student performance as the focus of today’s educational environments, the results of this study might lead the Sharpening Math Skills Lab stakeholders to feel that their efforts and resources were not effective. The fact that no significant difference was found between the mathematics achievement of the
experimental and control groups does not automatically mean that the project should be
construed as unsuccessful. It is possible that greater gains in academic achievement might be
made if the implementation is studied for a longer period of time.

The Sharpening Math Skills Lab students are receiving 45 minutes per day of multimedia
remediation at their current level of performance and 45 minutes per day of regular math
instruction on their grade level specific GLEs. Although some students are functioning two or
three grade levels below their current grade placement, they are only assessed on grade level
GLEs in this study. If the experimental group students can hold their ground academically over
the first five months of implementation with their math-delayed counterparts who are not
receiving technology-mediated remediation, then the long term effects on student achievement
and self confidence in math are worth investigating. Measuring the effects of filling in these
“potholes” or gaps student mathematical foundations will provide important data on technology-
mediated remedial instruction and program implementation. Investigating the long term effects
that step-wise remedial instruction has on student self confidence and attitudes toward
mathematics will also yield valuable data. The Sharpening Math Skills Lab project should
continue to be refined, evaluated, and closely examined for other effects to student affective and
cognitive domains that were included in this study.

The most immediate implication for practice is using these study results to refine the
Sharpening Skills Math Lab program implementation. To provide the math-delayed students at
Middle School One with optimal instructional opportunities, this researcher recommends that the
students receive 90 minutes of math instruction per day in the regular classroom like their control
group counterparts and use the Sharpening Math Skills Lab program for remedial or
supplemental instruction for 45 minutes per day.
Another implication for practice is the observed disconnect between the remedial curriculum and the regular mathematics curriculum. Students in the Sharpening Math Skills Lab are working at their own pace through a “stand alone” mathematics curriculum specifically designed to address their own strengths and weaknesses. Their daily math activities in the lab may or may not correlate to what they are studying in their regular math classes. This researcher recommends restructuring the order in which the Larson iSucceed lesson modules are presented to synchronize them with regular classroom instruction and provide immediate contextual practice for the new skills mastered.

According to Hooper and Hokanson (2000), most instruction utilizes technology for its own sake, without authentic integration into other school subjects, and is primarily focused on drill and practice instruction. To avoid the label of “canned” technology programming it is also recommended by this researcher that the Sharpening Math Skills Lab project facilitator review additional software programs that are rich in the proper application of the principles of instructional design that will translate to greater mathematical problem solving ability. The addition of technology-mediated group instruction through the use of an Activboard will enable teachers to link regular and remedial math instruction in the Sharpening Math Skills Lab.

An important implication for practice relating to the affective domains was gleaned from the results of the qualitative portion of this study. The students in the collective case study interviews agreed that the math facts they mastered in FASTTMath and the problem solving activities in Larson iSucceed were beneficial to them in their work in regular math classes. They also expressed satisfaction with their performance in the lab and enjoyment of the software. Whole class observations revealed that students demonstrated high levels of engagement in using both software programs.
The results of the Attitudes Toward Math Inventory (ATMI) in this study indicate that many of the math-delayed students in the Sharpening Math Skills Lab value mathematics, but lack confidence in their ability to do math. Based on the affective evidence, this researcher recommends continued use of FASTTMath and modified use of Larson iSucceed software to provide greater correlation to regular mathematics instruction. This researcher also recommends that greater effort to incorporate lab activities into other subject areas including science in which mathematics is heavily embedded is recommended to increase student motivation and build self-confidence.

There are no immediate financial implications for the Sharpening Math Skills Lab as the project has already been funded for three full years by the corporate sponsor. The implications for practice for the Sharpening Math Skills Lab are embedded in the refinement of the program implementation with additional software of specific instructional design quality, adjusting the amount of time students spend in daily math instruction, and broadening the lab activities to include other subject areas such as science.

Summary of Recommendations for Practice

In summary, this researcher’s recommendations for practice are listed below.

Multimedia Practices

- Software developers should pay greater attention to cognitive processes such as spatial visualization in the creation of educational software programs.
- Instructors should purchase software that best addresses cognitive functions instead of looking solely at program content or novelty features.
Sharpening Math Skills Lab Practices

- Students should receive 90 minutes of math instruction per day in the regular classroom and use the Sharpening Math Skills Lab program for remedial or supplemental instruction for 45 minutes per day.
- Continued use of FASTTMath and modified use of Larson iSucceed software is recommended to provide greater correlation to regular mathematics instruction.
- The order in which the Larson iSucceed lesson modules are presented should be restructured to synchronize them with regular classroom instruction and provide immediate contextual practice for the new skills mastered.
- To avoid the label of “canned” technology programming, the Sharpening Math Skills Lab project facilitator should review additional software programs that are rich in the proper application of the principles of instructional design that will translate to greater mathematical problem solving ability.
- Technology-mediated group instruction through the use of an Activboard should be incorporated which will enable teachers to link regular and remedial math instruction in the Sharpening Math Skills Lab.
- Greater effort to incorporate lab activities into other subject areas including science in which mathematics is heavily embedded will increase student motivation and build self-confidence.

Limitations of the Study

In this section, the research design used in this study is compared with best practices in research to ensure that the findings of this study may be fairly and accurately interpreted and that study findings influence multimedia remedial mathematics instruction in a practical and useful manner. Limitations of the study in terms of research design that warrant examination includes
the implementation of a quasi-experimental research design and the length of time of the study. Limitations that relate to the qualitative components include researcher bias and the establishment of trustworthiness. The quantitative limitations of the study are primarily the threats to internal validity which include history, maturation, testing, instrumentation, and regression artifacts.

Research Design

The “gold standard” of research design is considered to be the random assignment of subjects with design or statistical control of potentially confounding variables. As discussed in Chapter Three, random assignment is often not feasible in real world settings because of practical constraints. To address practical considerations, most experimental researchers do not select random samples, but rather use convenience samples (Johnson & Christiansen, 2004).

This study is quasi-experimental because the experimental and control groups of math-delayed students were already in place in the participating middle schools. Even though the study utilizes convenience sampling, the large number of study participants and the use of Analysis of Covariance (ANCOVA) to adjust for existing differences in the experimental (N = 109) and control groups (N = 162) enhances the generalizability of these research findings to a population.

The use of one group pretest-posttest design with the experimental group in measuring their spatial visualization ideally gauges the effectiveness of the treatment condition. Any change in the posttest scores over the pretest scores cannot be automatically be taken as an index of an effect produced by the independent variable (Johnson & Christiansen, 2004). The potentially confounding extraneous variables which can influence posttest results are examined in the next section.
Quantitative Research Validity

The possible limitations created by the quantitative research validity constructs of history, maturation, testing, instrumentation, and regression artifacts are discussed in this section.

While a longitudinal study would yield more data to compare the academic achievement of the control and experimental groups, the five-month length of this study is helpful in addressing the issues history and maturation of subjects in a positive manner. As history refers to the specific events, other than any planned treatment event, that occur between the first and second measurement of the dependent variable (Johnson & Christensen, 2004), it is unlikely that the five-month period in which the experimental and control group students were assessed for their mathematics achievement levels would have a significant effect on the results. Middle school students will naturally experience cognitive maturation during this time period, but the use of assessments administered to the control and experimental groups within the same time frame minimizes this concern.

Instrumentation refers to any change that occurs in the measuring instrument (Johnson & Christensen, 2004). As discussed in Chapters Three and Four, the Scantron Achievement Series tests are considered pseudo-independent and therefore cannot be used as a pretest – posttest measurement. This instrumentation concern was handled through the use of two separate ANCOVAs to assess differences in control group and experimental group mathematical achievement. The use of the WSAT for both the pretest and the posttest limits spatial visualization instrumentation validity concerns. The testing issue is addressed previously in the Spatial Visualization section of this chapter.

Qualitative Research Validity

In qualitative research establishing trustworthiness is essential to the defensibility of the research findings and is addressed in the discussion of the constructs of credibility, transferability,
dependability, and confirmability in Chapter Five. In this particular study the effort to consciously avoid obtaining results consistent with what the researcher wants to find is of significance as the researcher is the Sharpening Math Skills Lab project facilitator. With the researcher acting as a participant observer the issue of potential researcher bias had to be handled so the results would be received as plausible, credible, trustworthy, and therefore defensible (Johnson & Christensen, 2004). The use of peer debriefers and regular engagement in reflexivity or critical self-reflection enable the researcher to remain self-aware and control bias.

Recommendations for Further Study

The results of this study have generated several recommendations for further study of multimedia instruction for effects on academic achievement, spatial visualization, and the implementation of the principles of instructional design.

Academic Achievement

The recommendations for further study to determine the effects of multimedia on academic achievement are twofold. Longitudinal studies and studies related to multimedia software usage in all subject areas are recommended to aid in curricular and budgetary decision making processes.

This researcher advocates longitudinal studies of both supplemental and core Computer Assisted Instruction (CAI) which measure the effects on academic achievement of the same students over a period of several years. Studies tracking the same group of students over time instead of relying on disconnected “snapshots” or vignettes will provide a complete picture of multimedia program implementation.

Additional studies of multimedia instruction from all subject areas are needed to determine which subjects are amenable to multimedia instructional practices. Studies of multimedia programs which incorporate multi-subject content will also be useful.
Spatial Visualization

Multimedia has been reported to work best for individuals with high spatial ability and low prior knowledge (Mayer & Sims, 1994). This was evidenced by the students selected to participate in the collective case study. The tremendous growth in spatial visualization skills by the experimental group warrants further investigation. According to Wheatley (1991) spatial visualization skills are a predictor of a student’s mathematical problem solving ability. The students in the Sharpening Math Skills Lab demonstrated a statistically significant increase in their spatial visualization skills over a three month period, but this did not translate into a high correlation of these skills and mathematical achievement during the same time period. Taking Wheatley’s (1991) assertion into consideration, it would be useful to determine the effect of spatial visualization on mathematics achievement over a longer period of time. It would also be of interest to determine a spatial visualization national percentile achievement range that correlated to an anticipated hierarchy of mathematical problem solving ability.

Principles of Instructional Design

This study evaluated the multimedia mathematics software programs of FASTTMath and Larson iSucceed for implementation of principles of instructional design (Moreno & Mayer, 2000). Further study on the cognitive effects of these principles and other specific attributes of software interfaces is recommended. With careful attention to implementation, multimedia is proven to support learning (Mayer, 1997; Najjar, 1996). An instrument such as this researcher’s Principles of Instructional Design Observation Protocol (PIDOP) or Doolittle’s (2001) holistic rubric of examples of implementation of Moreno and Mayer’s (2000) principles of instructional design is a good starting point for further study and refinement for the purpose of evaluating software interfaces for their impact on cognitive functioning.
Conclusion

This study fulfilled its purpose in determining if the Sharpening Math Skills Lab technology-mediated mathematics instructional practices for math-delayed middle school students have positive effects on their mathematics achievement and spatial visualization ability, and to gauge student engagement in learning, implementation of the principles of instructional design, and attitudes toward mathematics instruction.

The results of the effects on mathematics academic achievement were that no significant difference exists between the Sharpening Math Skills Lab students and their control group counterparts after five months of instruction. The most significant finding in this study was the statistically significant growth in spatial visualization skills among the students in the experimental group as measured by the WSAT pretest and posttest. Also of interest was the small positive correlation between their spatial visualization skills and mathematics achievement and the high level of student engagement as they worked in the lab. These findings, coupled with the evaluation of the software featured in the Sharpening Math Skills Lab, promote development and application of a cognitive theory of multimedia learning that will create learner-centered technology rich environments for students that will ultimately lead to increased student achievement and self-efficacy.
REFERENCES


APPENDIX A

WHEATLEY SPATIAL ABILITY TEST (WSAT)
Name ____________________  Teacher's Name ____________________

Age _______ Birthdate _________  Grade _______  Boy  Girl

Caucasian(White)  African American  Hispanic  Asian  Other

WHEATLEY SPATIAL ABILITY TEST

Form B

This is a test of your ability to see differences in figures. Look at the five shapes below.

[Shapes shown]

All of these shapes are alike, but turned in different positions. Now look at the two triangles below.

[Two triangles shown]

These two triangles are NOT alike. The first cannot be made to look like the second by turning. It would have to be flipped over.

This test consists of sets of drawings, one drawing on the left of a vertical line and five problem drawings on the right. For each problem, you are to decide if the problem figure is like the figure on the left of the vertical line. If yes, circle the Y for that problem; if no circle N for that problem. Try the examples:

[Shapes shown with Ys andNs marked]

Examples 1, 3, and 4 are the same as the figure on the left of the vertical line, just turned in different positions. Examples 2 and 5 have to be flipped over to match the drawing on the left, so they are not the same as the left figure. So the answers you should have marked are Y, N, Y, Y, N. Work as quickly as you can, but not so fast that you make careless errors.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

© Grayson H. Wheatley. 1978. 1996
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APPENDIX B

ATTITUDES TOWARD MATH INVENTORY (ATMI)
ATTITUDES TOWARD MATHEMATICS INVENTORY

Directions: This inventory consists of statements about your attitude toward mathematics. There are no correct or incorrect responses. Read each item carefully. Please think about how you feel about each item. Darken the circle that most closely corresponds to how the statements best describes your feelings. Use the following response scale to respond to each item.

PLEASE USE THESE RESPONSE CODES:  
A – Strongly Disagree  
B – Disagree  
C – Neutral  
D – Agree  
E – Strongly Agree

1. Mathematics is a very worthwhile and necessary subject.  
2. I want to develop my mathematical skills.  
3. I get a great deal of satisfaction out of solving a mathematics problem.  
4. Mathematics helps develop the mind and teaches a person to think.  
5. Mathematics is important in everyday life.  
6. Mathematics is one of the most important subjects for people to study.  
7. High school math courses would be very helpful no matter what I decide to study.  
8. I can think of many ways that I use math outside of school.  
9. Mathematics is one of my most dreaded subjects.  
10. My mind goes blank and I am unable to think clearly when working with mathematics.  
11. Studying mathematics makes me feel nervous.  
12. Mathematics makes me feel uncomfortable.  
13. I am always under a terrible strain in a math class.  
14. When I hear the word mathematics, I have a feeling of dislike.  
15. It makes me nervous to even think about having to do a mathematics problem.  
16. Mathematics does not scare me at all.  
17. I have a lot of self-confidence when it comes to mathematics  
18. I am able to solve mathematics problems without too much difficulty.  
19. I expect to do fairly well in any math class I take.  
20. I am always confused in my mathematics class.  
21. I feel a sense of insecurity when attempting mathematics.  
22. I learn mathematics easily.  
23. I am confident that I could learn advanced mathematics.  
24. I have usually enjoyed studying mathematics in school.  
25. Mathematics is dull and boring.  
26. I like to solve new problems in mathematics.  
27. I would prefer to do an assignment in math than to write an essay.  
28. I would like to avoid using mathematics in college.  
29. I really like mathematics.  
30. I am happier in a math class than in any other class.  
31. Mathematics is a very interesting subject.  
32. I am willing to take more than the required amount of mathematics.  
33. I plan to take as much mathematics as I can during my education.  
34. The challenge of math appeals to me.  
35. I think studying advanced mathematics is useful.  
36. I believe studying math helps me with problem solving in other areas.  
37. I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in math.  
38. I am comfortable answering questions in math class.  
39. A strong math background could help me in my professional life.  
40. I believe I am good at solving math problems.

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APPENDIX C

THE LOUISIANA SYSTEMIC INITIATIVES PROGRAM (LASIP)
CLASSROOM OBSERVATION PROTOCOL (LASOP)
LaSIP CLASSROOM OBSERVATION PROTOCOL (LaSOP)

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<th># of Students Present</th>
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Elements of Instruction

(Complete after concluding the Observation)

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Student Engagement

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Cognitive Levels Activity

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<td>2</td>
<td>Low: Application of Procedural Knowledge</td>
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<td>High: Knowledge Representation</td>
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<td>High: Knowledge Construction</td>
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Comments:

Student Engagement Descriptors

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<td>Eff</td>
<td>Making efforts in tackling difficult questions</td>
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<td>Pos</td>
<td>Commenting positively on the learning activities</td>
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LaSIP

Revised 10-2007
APPENDIX D

PRINCIPLES OF INSTRUCTIONAL DESIGN OBSERVATION PROTOCOL (PIDOP)
Principles of Instructional Design Observation Protocol (PIDOP)

Software Title: ________________________________
Date: ________________________________
Length of time observed: ________________________________

Directions: Place a tally mark in the blank for each software characteristic observed.

Verbal information is presented as text:

1. ______ concurrently with onscreen graphics or animations
2. ______ preceding onscreen graphics or animations
3. ______ following onscreen graphics or animations
4. ______ physically integrated or close to onscreen graphics or animations
5. ______ physically far from onscreen graphics or animations
6. ______ in small chunks preceding or following a small chunk of graphics or animation

____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

Verbal information is presented auditorily:

7. ______ concurrently with onscreen graphics or animations
8. ______ preceding onscreen graphics or animations
9. ______ following onscreen graphics or animations
10. ______ in small chunks preceding or following a small chunk of graphics or animation

____________________________________________________________________________

11. ______ Verbal information is presented both auditorily and as text concurrently with onscreen graphics or animations
12. ______ Additional auditory information such as music or sounds is presented

Notes:
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________
____________________________________________________________________________

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Scoring Key

The Split Attention Principle: Students learn better when the instructional material does not require them to split their attention between multiple sources of mutually referring information.

Indicators: 2, 3, 7, 8, 9

The Modality Principle: Students learn better when the verbal information is presented auditorily as speech rather than visually as on-screen text both for concurrent and sequential presentations.

Indicators: 7, 8, 9

The Redundancy Principle: Students learn better from animation and narration than from animation, narration, and text if the visual information is presented simultaneously to the verbal information.

Indicator: 7, 11

The Spatial Contiguity Principle: Students learn better when on-screen text and visual materials are physically integrated rather than separated.

Indicators: 1, 4, 5

The Temporal Contiguity Principle: Students learn better when verbal and visual materials are temporarily synchronized rather than separated in time:

Indicators: 6, 10

The Coherence Principle: Students learn better when extraneous material is excluded rather than included in multimedia explanations.

Indicator: 12

Created by the Lisa L. Stokes based on the research of Dr. Roxana Moreno and Dr. Richard Mayer.

APPENDIX E

SHARPENING MATH SKILLS LAB STUDENT INTERVIEW PROTOCOL
Sharpening Math Skills Lab Student Case Study Interview Protocol

1. How does learning math in the Sharpening Math Skills Lab compare with learning math in your regular math classes?
2. What do you like best about working in the Sharpening Math Skills Lab?
3. What do you like least about working in the Sharpening Math Skills Lab?
4. Which program do you like working with best in the Sharpening Math Skills Lab and why?
5. Do you feel that the math facts you have learned with FASTTMath have helped you with your work in Larson iSucceed Math and your regular classroom math lessons?
6. Do the reward features of FASTTMath make you work harder to learn your math facts?
7. When you use Larson iSucceed, does listening to the problem help you solve it?
8. About how many times do you listen to a problem while working it?
9. What other features (e.g. online calculator, glossary, problem review, answer feedback) of the Larson iSucceed software do you feel are helpful?
10. If you could change one thing about the Sharpening Math Skills Lab, what would that be?
Application for Exemption from Institutional Oversight

Unless qualified as meeting the specific criteria for exemption from Institutional Review Board (IRB) oversight, ALL LSU research/projects using living humans as subjects, or samples or data obtained from humans, directly or indirectly, with or without their consent, must be approved or exempted in advance by the LSU IRB. This Form helps the PI determine if a project may be exempted, and is used to request an exemption.

- Applicant, Please fill out the application in its entirety and include the completed application as well as parts A-E, listed below, when submitting to the IRB. Once the application is completed, please submit two copies of the completed application to the IRB Office or to a member of the Human Subjects Screening Committee. Members of this committee can be found at http://appl003.lsu.edu/osp/osp.nsf/$Content/Humans+Subject+Committee?OpenDocument

- A Complete Application Includes All of the Following:
  (A) Two copies of this completed form and two copies of parts B thru E.
  (B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1 & 2)
  (C) Copies of all instruments to be used.
    - If this proposal is part of a grant proposal, include a copy of the proposal and all recruitment material.
  (D) The consent form that you will use in the study (see part 3 for more information.)
  (E) Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing or handling data, unless already on file with the IRB.

Training link: (http://cme.cancer.gov/clinicaltrials/learning/humanparticipant-protections.asp)

1) Principal Investigator: **Lisa L. Stokes** Rank: **Doctoral Student**
Dept: [ ] Ph: [ ] E-mail: [ ]

2) Co Investigator(s): please include department, rank and e-mail for each
   - Dr. Yiping Lou, ETPP

3) Project: Multimedia Mathematics Intervention for Math-Delayed Middle School Students

4) LSU Proposal? (yes or no) **no** If Yes, LSU Proposal Number [ ]
   - Also, if YES, either **□** This application completely matches the scope of work in the grant
   - **□** More IRB Applications will be filed later

5) Subject pool (e.g. Psychology Students)/Middle School Students
   - "Circle any "vulnerable populations" to be used: children, the mentally impaired, pregnant women, the aged, other. Projects with incarcerated persons cannot be exempted.

6) PI Signature: **Lisa L. Stokes** **Date 6/23/07** (no per signatures)
   - "I certify my responses are accurate and complete. If the project scope or design is later changed I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at LSU for three years after completion of the study. If I leave LSU before that time the consent forms should be preserved in the Departmental Office.

   "Effective August 1, 2007, all Exemptions will expire three years from date of approval, unless a continuation report, found on our website, is filed prior to expiration date***

Screening Committee Action: Exempted [ ] Not Exempted [ ]
Category/Paragraph [ ]
Reviewer [ ] Signature [ ] Date 11/15/07
Louisiana State University Parent Consent Form for Academic Research

Project Title: Multimedia Mathematics Intervention

Performance Site: [Redacted] Middle School

Investigator: Lisa L. Stokes, Master Teacher at [Redacted] Middle School and doctoral student at Louisiana State University

Purpose of the Study: The purpose of this research project is to determine whether students who participate in mathematics Computer Assisted Instruction classes will perform better on academic achievement tests than students of similar ability who do not participate in Computer Assisted Instruction for mathematics.

Inclusion Criteria: Middle school students who have been scheduled for the Skills for Life Mathematics Lab due to scoring Unsatisfactory or Approaching Basic on the Spring 2007 iLEAP test.

Exclusion Criteria: Middle school students who do not meet the academic requirements or those who have missing or incomplete test data.

Description of the Study: The study will be conducted in two phases. The students will not have to do anything out of the ordinary for the first phase in which the researcher will examine the scores from the mathematics portion of the iLEAP which is given to all public school students in Louisiana and the mathematics Scantron Performance Series and Achievement Series test which are given to all students in Calcasieu Parish Schools. In the second phase subjects will be asked to spend approximately 36 minutes to take two tests of visual mathematics ability and fill out a questionnaire on their attitudes toward mathematics. The researcher will also conduct observations of the students as they work in their regular mathematics class activities.

Benefits: The subjects will receive a pizza party for participating in the study. This study will yield valuable information on whether Computer Assisted Instruction for mathematics improves academic achievement.

Risks: There are no known risks.

Right to refuse: Participation is voluntary, and a child will become part of the study only if both child and the parent agree to the child’s participation. At any time, either the subject may withdraw from the study or the subject’s parent may withdraw the subject from the study without penalty or loss of any benefit to which they might otherwise be entitled.

Privacy: The school records of participants may be reviewed by researchers. Results of the study may be published, but no names or identifying information will be included in the publication. Subject identity will remain confidential unless disclosure is required by law.
Financial Information: There is no cost for participating in the study, nor is there any compensation to the subjects for participation.

Signatures: The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. If I have question about subjects’ rights or other concerns, I can contact Robert C. Mathews, Institutional Review Board (225) 578-8692. I agree to allow my child to participate in the study described above and acknowledge the investigator’s obligation to provide me with a signed copy of this consent form.

__________________________
(Student Name)

__________________________   _____________
(Parent’s Signature)               (Date)

The parent/guardian has indicated to me that he/she is unable to read. I certify that I have read this consent form to the parent/guardian and explained that by completing the signature line above he/she has given permission for the child to participate in the study.

__________________________   _____________
(Signature of Reader)               (Date)

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-8692 | www.lsu.edu/wirb
Exemption Expires: 11-4-10
Louisiana State University Student Consent Form for Academic Research

I, ____________________________, agree to participate in a study to determine whether students who participate in mathematics Computer Assisted Instruction classes will perform better on academic achievement tests than students of similar ability who do not participate in Computer Assisted Instruction for mathematics.

In addition to my regular work in the Skills for Life Math lab, I will take two 8 minute visual mathematics tests and one 20 minute math attitude survey.

I can decide to stop participating in the study at anytime.

______________________________
(Student Name)

______________________________   __________________________
(Student’s Signature)   (Date)

______________________________   __________________________
(Witness Signature)   (Date)

Study Exempted By:
Dr. Robert C. Mathews, Chairman
Institutional Review Board
Louisiana State University
203 B-1 David Boyd Hall
225-578-3692 | www.lsu.edu/irb
Exemption Expires: 4/3/2011
APPENDIX G

CALCASIEU PARISH SCHOOLS RESEARCH CONSENT FORM
Application requesting permission to do Graduate Study in Calcasieu Parish Public Schools
Name of Graduate Student: Lisa L. Stokes
Home Address: [Redacted] Lake Charles LA 70605
Home Telephone: [Redacted]
Local Address (if different): Same
Local Telephone: (if different): Same
Current Place of Employment: Calcasieu Parish Schools
Position: Master Teacher
Business Telephone: [Redacted] Home Telephone: [Redacted] Cell: [Redacted]
Email Address: lisa.stokes@cpsb.org
Title of Study: Multimedia Mathematics Instruction

Name of University: Louisiana State University
Location of University: Baton Rouge, LA
Proposed Time Period for conducting study: 2007-2008 school year
Purpose of study: To determine the level of student academic growth from interactive multimedia math activities.

What value will Calcasieu Parish School Board derive from information obtained from this study? (NOTE: THIS IS THE PRIMARY PURPOSE FOR CONDUCTING RESEARCH STUDIES IN CALCASIEU PARISH SCHOOLS)
Qualitative and quantitative data from the study will enable CPSB to determine the effectiveness of the Certainment Skills for Life Math Lab.

How many local public schools will be involved in the study? 2
How will the schools be selected? Convenience and matching sampling strategies
How many public school students will be involved in this study? App. 60
How will the students be selected? Convenience and matching sampling strategies
In what kind/s of activities will students be involved? Interactive multimedia math instruction
How much displacement time of students will the study require? NONE
How many public school teachers/administrators/other staff will be involved in this study? 8
In what kinds of activities will teachers or staff be expected to participate? Survey, regular instruction
How will the teachers or staff be selected? Convenience and matching sampling strategies
Graduate Student,

Please sign the following agreement:

(1) I agree to abide by all Calcasieu Parish School Board policies and procedures while carrying out my proposed research study.

(2) I will maintain confidentiality of all research subjects at all times.

(3) I agree not to publish or disseminate in any form any part of the research findings to any person, agency, or institution other than the above-named university and Calcasieu Parish School Board without written approval of the Calcasieu Parish School Board Superintendent or his authorized designee.

(4) I further agree that two progress reports will be submitted to the Calcasieu Parish School during the time my study is being pursued, and a complete copy of the research study will be submitted once the study is finished. All reports will be submitted to the Administrative Director of Assessment, Research, Special Services, and Accountability, Calcasieu Parish School Board.

Signature of Graduate Student
August 24, 2007

Approval Signature of Major Professor for Proposed Study

For use by Calcasieu Parish School Board personnel only:

Date Request Received: ____________________________

Calcasieu Parish School Board Research Project No. ____________________________

Graduate Study Researcher ____________________________

Title of Research Study ____________________________

Request approved ____________________________

Sept.

10-18-07
FIGURES 2.1 and 2.2

From: Roxana Moreno [mailto:moreno@unm.edu]
Sent: Friday, January 04, 2008 10:20 AM
To: stokes, lisa
Subject: Re: Permission to use diagrams

Sure, just indicate something along the lines of "from Moreno ... Printed with permission."
Thank you for asking!

----- Original Message ----- 
From: stokes, lisa
To: moreno@unm.edu
Sent: Friday, January 04, 2008 8:11 AM
Subject: Permission to use diagrams

Dr. Moreno,

I am a doctoral student at Louisiana State University and am writing my dissertation on multimedia mathematics remedial instruction. I am using your six principles of instructional design to evaluate the software used in the research project and would like to include two of your diagrams in my dissertation – Cognitive Theory and Split Attention principle. May I have your permission to do so?

Thank you!

Lisa L. Stokes
Doctoral Student
Louisiana State University

"Think Like A Person of Action - Act Like A Person of Thought"
From: Rich Mayer [mailto:mayer@psych.ucsb.edu]
Sent: Friday, January 04, 2008 11:01 AM
To: stokes, lisa
Subject: Re: Permission to use diagrams in dissertation

Yes, you have my permission to use any of my materials for research purposes. Best wishes, Dr. Mayer

--------------------------------------------------
Richard E. Mayer
Department of Psychology
University of California
Santa Barbara, CA 93106-9660
805-893-2472
mayer@psych.ucsb.edu
--------------------------------------------------

On Jan 4, 2008, at 7:11 AM, stokes, lisa wrote:

Dr. Mayer,
I am a doctoral student at Louisiana State University and am writing my dissertation on multimedia mathematics remedial instruction. I am using your six principles of instructional design to evaluate the software used in the research project and would like to include two of your diagrams in my dissertation – Cognitive Theory and Split Attention principle. May I have your permission to do so?
Thank you!
Lisa L. Stokes
Doctoral Student
Louisiana State University

"Think Like A Person of Action - Act Like A Person of Thought"

FIGURES 2.3, 3.1, 3.2, 3.3, 3.4, and 3.5

Verbal permission to use Tom Snyder Production FASTTMath diagrams published in Research Foundation & Evidence of Effectiveness for FASTTMath granted via telephone conversation with James at 1-800-342-0236 on January 4, 2008 at 9:20 AM.
February 21, 2008

Lisa Stokes
Middle School
Lake Charles, LA 70607
FX: 337-

Dear Ms. Stokes:

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Sincerely,

Karin Huang
Associate Editor
APPENDIX I

PERMISSION TO USE THE ATMI
Dear Lisa,

You have permission to use the ATMI. Since you will be using the ATMI for your dissertation research there is no charge for using it.

This information will help you score the ATMI.

Scoring Key

The following items are reversed.

For your analysis, use the formula e.g. it12 = 6 - it12 to get the correct value.

9. Mathematics is one of my most dreaded subjects.

10. My mind goes blank and I am unable to think clearly when working with mathematics.

11. Studying mathematics makes me feel nervous.

12. Mathematics makes me feel uncomfortable.

13. I am always under a terrible strain in a math class.

14. When I hear the word mathematics, I have a feeling of dislike.

15. It makes me nervous to even think about having to do a mathematics problem.

20. I am always confused in my mathematics class.

21. I feel a sense of insecurity when attempting mathematics.

25. Mathematics is dull and boring.

28. I would like to avoid using mathematics in college.

Subscales

Self-confidence: Items 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22 & 40

Value: Items 1, 2, 4, 5, 6, 7, 8, 35, 36 & 39

Enjoyment: Items 3, 24, 25, 26, 27, 29, 30, 31, 37 & 38

Motivation: Items 23, 28, 32, 33 & 34

If you have any question, please do not hesitate to ask me.
Martha Tapia

Martha Tapia, Ph.D.
Associate Professor
Department of Mathematics and Computer Science
Berry College
Mount Berry, Georgia 30149
VITA

Lisa Laine Stokes is the daughter of professional educators and life long learners, W. P. “Whit” and Sybil Stokes of Oakdale, Louisiana. She graduated from Oakdale High School in 1977. After attending Louisiana State University at Alexandria and earning a bachelor’s degree from McNeese State University she began teaching for Calcasieu Parish Schools in 1980. A master’s degree from McNeese State University followed in 1981. Teaching and spending time with her sons, John and Will, were the foci of her life during subsequent years. A Master’s Plus Thirty accumulated in 1988 as a result of her ongoing interest in professional improvement.

During her career as a classroom teacher at Maplewood Middle School, Lisa became interested in online collaborative learning which led to a sixteen-year partnership with Global SchoolNet Foundation, first as a volunteer system operator, then as a member of their Board of Directors. Leaving Maplewood in 2001 to facilitate Calcasieu Parish School’s first Carnegie Unit online course for students in seven high schools, Lisa served in that capacity for three years. Upon returning to teaching middle school mathematics at W. W. Lewis and S. P. Arnett Middle Schools, Lisa earned National Board for Professional Teaching Standards Certification in Early Adolescence Mathematics. In 2005 Lisa joined Calcasieu Parish’s Teacher Advancement Program (TAP) as a Math Master Teacher, serving in Ray D. Molo and Forrest K. White Middle Schools.

Lisa and her fiancé, Adam McBride, make their home in Lake Charles, Louisiana. Utilizing her doctoral studies research in helping math-delayed students improve their academic achievement in mathematics by serving as the Sharpening Math Skills project coordinator, Lisa is immersed in doing what she loves – teaching, and learning.