MATH FACT AUTOMATICITY AND ITS EFFECT ON STUDENT MATH ACHIEVEMENT IN A NORTHERN CALIFORNIA SCHOOL DISTRICT

A Thesis
Presented
to the Faculty of
California State University, Chico

In Partial Fulfillment
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Master of Arts
in
Education
Educational Leadership and Administration Option

by

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Anne M. McLean

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DEDICATION

This thesis work is dedicated to my husband, Scott, who has been a constant source of support and encouragement during the challenges of graduate school and life. I am truly thankful for having you in my life. This work is also dedicated to my parents, Robert and Cecelia, and my parents-in-law, Don and Joanne, who have always loved me unconditionally and by whose good example have taught me to work hard for the things that I aspire to achieve. And lastly, to my children and grandchildren:

“Don’t be afraid to go out on a limb. That’s where the fruit is.”

Author Unknown
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# TABLE OF CONTENTS

| PAGE |
|-------------------------------|---|
| Publication Rights | iii |
| Dedication | iv |
| Acknowledgements | v |
| List of Tables | viii |
| List of Figures | ix |
| Abstract | x |

## CHAPTER

### I. Introduction

- Background | 1 |
- A Local Approach to the Problem | 3 |
- Statement of the Problem | 4 |
- Theoretical Bases and Organization | 5 |
- Limitations of the Study | 5 |
- Definition of Terms |

### II. Literature Review

- Introduction | 8 |
- Background Information | 9 |
- Changes in Education in American Schools | 11 |
- Student Mathematical Learning | 18 |
- Acquisition of Math Fact Automaticity | 22 |
- The Teaching of Math Fact Strategies/Methodologies | 24 |
- Effect of Automaticity on Student Test Scores | 28 |
- Summary |
<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>III. Methodology</td>
<td>30</td>
</tr>
<tr>
<td>Description of Experimental and Control Groups</td>
<td>31</td>
</tr>
<tr>
<td>Description of the Intervention</td>
<td>31</td>
</tr>
<tr>
<td>Measurements</td>
<td>35</td>
</tr>
<tr>
<td>Collection of Data</td>
<td>36</td>
</tr>
<tr>
<td>IV. Findings and Results</td>
<td>37</td>
</tr>
<tr>
<td>Objective Data</td>
<td>37</td>
</tr>
<tr>
<td>Teacher Reported Observations</td>
<td>38</td>
</tr>
<tr>
<td>V. Summary, Conclusions, and Recommendations</td>
<td>43</td>
</tr>
<tr>
<td>Summary</td>
<td>43</td>
</tr>
<tr>
<td>Conclusions</td>
<td>43</td>
</tr>
<tr>
<td>Recommendations for Further Research</td>
<td>44</td>
</tr>
<tr>
<td>Attitudinal Based Recommendations</td>
<td>46</td>
</tr>
<tr>
<td>References</td>
<td>48</td>
</tr>
</tbody>
</table>
## LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 2012-13 School Site</td>
<td>32</td>
</tr>
<tr>
<td>2. 2012-13 Sixth Grade Student Group Demographics</td>
<td>32</td>
</tr>
<tr>
<td>3. Accelerated Math Fluency Grade Level Benchmark Goals</td>
<td>33</td>
</tr>
<tr>
<td>4. <em>t</em>-Test Results Comparing Experimental and Control Groups on 2013 CST</td>
<td>38</td>
</tr>
<tr>
<td>5. Percent of Students at the Experimental School Meeting Math Fact Benchmarks</td>
<td>40</td>
</tr>
<tr>
<td>6. Experimental Group – Percent of Students Meeting Grade-Level Benchmark</td>
<td>41</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Experimental School-Wide Percentages of Students Meeting Grade-Level Benchmarks</td>
<td>39</td>
</tr>
<tr>
<td>2. Graph Demonstrates Same Student Progress For A Three-Year Period</td>
<td>42</td>
</tr>
</tbody>
</table>
ABSTRACT

MATH FACT AUTOMATICITY AND ITS EFFECT ON STUDENT MATH ACHIEVEMENT IN A NORTHERN CALIFORNIA SCHOOL DISTRICT

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Mathematics is considered to be a major factor in all aspects of modern society, with the root of mathematical capability stemming directly from classroom activity. Of great concern to educators, parents and policymakers in the United States is the inadequacy of mathematical achievement of American students.

The literature shows a conflict in this area, between the Traditionalists and Constructivists. The Traditionalists are of course steeped in traditional education, as found in the practice of rote learning such as in rote memorization of multiplication facts or of the rules of grammar. The Constructivists, by contrast, view learning as development of general mental concepts then applied toward any given area. The most important point is the former is teacher-driven, and the latter driven by students.
The present study was concerned with a particular approach drawing on both theories, which looked at an implementation by Renaissance Learning, Inc. called Accelerated Math Fluency, which was utilized in the researcher’s classroom. This classroom was compared with one, equal in most respects that did not implement this program.

Statewide annual standardized test scores of students in these two classrooms were analyzed. No statistical difference was found. The progress of students using the Accelerated Math Fluency intervention across grade levels and years at the experimental school was also investigated. These results showed considerable growth in math fact automaticity.

Recommendations for further research were made such as, increasing the sample size and grade levels of students in the sample, and complementing quantitative approaches with qualitative measures such as surveys of teachers to gather their reactions to, feelings about, and suggestions for using the particular intervention.
CHAPTER I

INTRODUCTION

Background

Mathematics is considered to be a major factor in all aspects of modern society with the root of mathematical capability stemming directly from classroom activity. A current concern of educators, both elementary and high school, parents, and policymakers in the United States is low performance of mathematical achievement across American students.

A multitude of reasons are put forth for this failure in student mastery of basic math facts. Though important in the school setting, this is no less important in situations found in one’s everyday life (Cowen & Donlan, 2011). Loveless gives three compelling motivations considered important in order for students to reach math fact mastery: 1) the demand for a more mathematically proficient workforce, 2) a predictor of future adult earnings, and 3) to promote equity in mathematics opportunities among racial groups (Loveless & Coughlan, 2004). For those with inadequate math skills the job market becomes narrow and limiting, and does not provide for upward career mobility. This in turn weakens the labor force and the economy as a whole suffers. Also, a student’s lack of computational skills has been linked to educational inequity and the widening of the achievement gap among racial groups, which feeds directly into one’s future adult career success and occupational and other opportunities (Loveless & Coughlan, 2004).
American students have not shown substantial growth in mathematics since the math reforms enacted in the 1980s and 1990s. With the No Child Left Behind Act (NCLB) in 2002, measurement of educational progress was primarily determined by scores on an annual standardized test with the goal that all students would reach proficiency by 2014. Toward this goal, students were assessed yearly with states tracking student achievement. In 2011, the results of the National Assessment of Educational Progress (NAEP) report showed only 40% of fourth graders and 35% of eighth graders performed at the proficient or advanced levels of mathematics.

These results suggest that students in the United States were still experiencing a lack of growth in computational skills and thereby compromised in their ability to have success with higher-order mathematical concepts (Loveless & Coughlin, 2004). Students who lack basic math fact automaticity struggle to keep up with the pace of more complex mathematical instruction, such as division and simple algebra in the elementary grades.

Experts agree that reaching automaticity of basic math facts is an essential factor in students’ ability to attain higher-order math skills and solve problems (Wong & Evans, 2007). The National Council of Teachers of Mathematics (NCTM) in 2000 recommended that high-quality math instruction should include computational skills. NCTM also states that students, upon leaving the sixth grade, must be proficient in computational skills that include whole numbers, fractions, decimals, and percentages. The National Math Advisory Panel (2008), along with the National Council of Teachers of Mathematics (2006), and Common Core State Standards in Mathematics (2010) are all in agreement that mastery and automaticity of basic math facts is an essential skill.
Math fact mastery, or “automaticity,” is the ability to recall answers quickly and without hesitation. Students who reach automaticity are better able to attend to more complex problem-solving math tasks while not being hindered by having to devote time to basic calculations.

A Local Approach to the Problem

In 2010, this researcher's school site was awarded a three-year grant offered by Renaissance Learning, Inc. a company that is considered authoritative in both math and reading assessment and learning analytics to improve student learning. This school was only one of thirty-six schools nationwide to be offered the opportunity to participates in the Renaissance Learning Lighthouse Grant program. The grant supported the implementation of assessment components (STAR Early Literacy, STAR Reading and STAR Math), student practice components (Accelerated Reader, Accelerated Math, and Accelerated Math Fluency), individual technology devices (Neo—a small computer-like entry device), and concentrated, on-going professional development for teachers and staff. Those administering the grant program held the school to high standards of implementation, as well as requiring other criteria applied to their design.

Participating in this grant, this researcher implemented Accelerated Math Fluency, a component of this program (described more fully below), in her sixth grade math classroom, as an intervention component designed to help students attain math fact automaticity. All students in the researcher’s classroom from 2010 to present, even those with an Individualized Education Plan (IEP), participated. Prior to students using the
program, this researcher set math fact objectives based on grade-level benchmarks provided by the company.

Statement of the Problem

Research has shown that in order for students to be successful at learning higher-order mathematical concepts and skills, they must possess automaticity of basic math facts (Wong & Evans, 2007). It is imperative that students develop the ability to recall math facts with speed and accuracy without the need for other math strategies (Stickney, Sharp, & Kenyon, 2012). Students at the researcher’s school, in order to successfully attain higher-order math concepts, need to possess automaticity of basic math facts.

There are several teaching strategies available to help students attain mastery of basic math facts. Of these, this study will assess the effectiveness of a particular strategy, Accelerated Math Fluency, a computer-assisted program designed for this purpose. Therefore, this study will test the hypothesis that students who have attained math fact automaticity outperform students lacking math fact automaticity when assessed on standardized mathematics achievement tests. This study will also examine math fact automaticity growth of students at the researcher’s school over a three year period.

Purpose of the Study

Mathematical growth and achievement of higher order math skills, in and outside the classroom, are a desired outcome for students. If this study shows that math fact automaticity and higher math achievement are linked, it may indicate that more appropriate and effective teaching practices be incorporated at all grade levels. Research
indicates math fact automaticity is beneficial to student achievement in successful learning of higher-order math concepts. Consensus has not yet been reached as to the most effective strategies to help students attain automaticity, or that it even provides for a significant influence on general math achievement. This is entertained as a further discussion in a later part of the thesis.

Theoretical Bases and Organization

Previous studies of Accelerated Math Fluency have been conducted with much larger sample sizes, but typically over shorter time periods (Renaissance, 2002). In conducting this local school study the researcher applied an action research model to the evaluation of Accelerated Math Fluency, a specific mathematics intervention, to determine the efficacy of the intervention in a northern California elementary school setting. The sample groups for the study consisted of an experimental group that used the Accelerated Math Fluency program, and a control group of same age students at a demographically comparable school that did not have access to the math facts program.

Limitations of the Study

This study was constrained by the following limitations:

- Samples used were not randomly selected. The experimental and control groups were both in place as classrooms such that random assignments could not be done.
- The resultant sample size was small, consisting of 136 grade students between the two schools.
• Collection of data was limited to a single assessment instrument; the math section of the California Standards Test (CST).

• Another limiting factor involved the use of data collected from the 2013 academic year only, as following years were not available due to a suspension of state standardized testing starting in 2014, as California transitioned to a Common Core State Standards format.

• This researcher recognizes that numerous other variables often affect student math achievement, but the study could not control for them other than using similar sixth grade classrooms. Such variables might include differing instructional styles among teachers, varying strategies and methodologies used in instruction and intervention, gender, racial and low socio-economic differences, learning disabilities, and differences found in a student’s math self-efficacy.

Definition of Terms

• Automaticity is the ability to recall information from long term memory without conscious effort or hesitation. In terms of math fact automaticity, a student is considered to have reached automaticity when they have attained basic math fact fluency, and can demonstrate a consistent accurate response within two seconds without reliance on any form of calculation or mental algorithm. (Stickney, Sharp, & Kenyon, 2012).

• Fluency is the term used to describe a student’s ability to quickly and accurately recall basic math facts (Frawley, 2012). Student fluency is often determined
through assessing the number of correct student responses per minute for a specific set of facts primarily consisting of: 1) addition, 2) subtraction, 3) multiplication, and 4) division facts.

- Basic math facts are referred to as answers to fundamental addition, subtraction, multiplication, and division facts used in everyday base 10 calculations (Spear-Swerling, 2006).
CHAPTER II

LITERATURE REVIEW

Introduction

Teachers are often at a loss to understand why a large number of their students enter math classrooms lacking the necessary skills to achieve current grade level expectations. The reason in many cases can be attributed to a student’s limited level of proficiency, or a complete lack thereof, of basic math fact computational skills. This observation has been cited by numerous researchers (Wong & Evans, 2007) who argue that successful mastery and automaticity of math facts form the foundation for future achievements in mathematics.

The present study is being conducted to determine if math fact automaticity--achieved through the use of a computer-based intervention program--can result in elementary students gaining higher levels of math automaticity and higher math achievement test scores. Is math fact automaticity essential to overall conceptual math growth? This literature review continues by looking at both current and past practices. Also considered below are philosophies of math education in the United States, followed by an exploration of how students learn mathematics. Specifically, how do students come to automaticity of basic math facts?
Background Information

There are a host of reasons why student proficiency and/or mastery of basic math facts are considered essential; none, however, is as important as the application of these principles to one’s everyday life (Cowen & Donlan, 2011).

Current thinking is that math skills are required for any and all activities, even those beyond the workplace. Virtually any activities in which people engage, such as household activities, pursuing of hobbies, and so many other activities one engages in daily life. There is no element of daily life that does not, in some way, require the use of some form of mathematics. As examples, dealing with one’s personal finances, adjusting recipes when cooking, understanding music theory, or following the progress of a baseball game.

It is frequently thought that careers in science, engineering, technology and finance are the only careers that rely on mathematics. Though this is certainly true for these fields, virtually all careers require some degree of mathematical application. Farmers, as an example, need these skills, as they must apply numerical reasoning in their daily farming practices (as in calculating the costs of feed, and calculating fertilizer mixes). Individuals lacking a competent mathematical foundation are often denied career opportunities, having a direct effect on potential earnings.

Disparities for students in cultural, racial, low-economic, and gender sub-groups are more likely to experience student failure in the acquisition of skills needed to participate fully in both college and career opportunities. This further adds to the difficulties mentioned above.
Research gives three compelling motivational factors in the attainment of math fact mastery and automaticity: 1) the demand for a more mathematically proficient workforce, 2) future adult earning capabilities affected by insufficient mastery and automaticity of mathematical proficiency, 3) and to promote equity in mathematics among racial and socioeconomic groups (Loveless & Coughlan 2004).

Hasselbring, cited by Scholastic Research (2012), states that a student’s inability to automatically recall math facts can inhibit class participation and performance, affect problem solving capabilities, negatively impact general life skills and, moreover, serves as a predictor of overall math performance on standardized tests. The researchers Axtell, McCallum, Mee Bell and Poncy, as cited in the work of Amy Bystrom (2010), wrote, “The need for higher levels of math competence has increased in this technology-based world, and a lack of knowledge, understanding, and skill development can close doors for students,” (Bystrom, 2010, p. 8).

The National Center for Fair and Open Testing (2007) remarked that the state of California often uses state standardized test scores to assign students to a variety of instructional groups (e.g., remediation, special education programs, and advanced student placements). Standardized scores are significantly used in the determining of school eligibility for federal funding, and influencing of decision making practices in regards to continued employment for educators (Fast et al., 2010).

With so much at risk for both students and educators based solely on student test scores, it is imperative that educators prepare for and afford students abundant opportunities to gain the skills needed to be successful. One strong predictor of student
performance in mathematics achievement tests has been found through the automaticity of math fact recall (Scholastic, 2012).

This is especially so in elementary school mathematics curriculum. Math fact automaticity has been shown to play an integral role in student achievement, extending into subsequent grade levels.

To address this increased concern for math fact automaticity, the NCTM Curriculum Focal Points (2006), National Mathematics Advisory Panel’s Core Principles of Math Instruction (2008) and Common Core State Standards (CCSS) for Mathematics (2010) have set national curriculum standards that target math fact automaticity as being a core standard and objective of elementary mathematics programs (Cholmsky, 2011).

Changes in Education in American Schools

During the 20th century, student mathematical achievements in America were unmatched; not only in the areas of engineering, science and finance, but in the overall quality of math education for the general population as well.

The Soviet Union, on October 4, 1957, launched, Sputnik, the first satellite, into space. The success triggered the 20th century “Space Race” between the United States and the Soviet Union and ushered in a new era of developments in science and technology. Both United States Presidents Eisenhower and Kennedy, feeling a sense of urgency to gain supremacy in the field of aeronautics and technology, called for increased spending on education, specifically in math and science for research and development, which led to advances in technology, as well as, of course landing a man on the moon.
Advances continue today in developments in computer systems, transportation systems, kitchen appliances, and even such as ready-to-eat food and no-fog ski goggles. These changes affect every aspect of society and of course, including education.

Traditional math education in the 1950s and 1960s was very traditional in its methodology. It was tightly regulated through federal, state and local policies, laws and protocols. The education model used at that time was that of the teacher lecturing students, who received that lecture in a passive manner, with no interaction taking place, other than the occasional question.

Mathematics curriculums were textbook-based, and were formulaic in its presentation. Class instruction was also formulaic. After a teacher’s lecture, students were assigned math problems from the textbook for both classwork and homework. Assessments consisted primarily of math calculations, given at the end of a unit of study, or, in a word, formulaic learning.

Mathematical education has been and still is designed as an incremental structure (i.e. building blocks), which are presented over the course of a student’s formal training. Ineffective training due to this model can prevent attainment of higher-order math concepts, therefore creating gaps in a student’s mathematical knowledge. This knowledge gap, in turn, can lower the success rate in college-level science and math courses. This of course can hinder the effectiveness of the American workforce to compete successfully within the global economy (Whitehurst, 2003).

Whitehurst (2003) also reports that the United States continues to experience a decline in the number of college degrees in technical areas, leading countries to outpace the United States in areas of math proficiency. As a result of the inability of the United
States to provide a mathematically proficient labor force, the Congress of the United States has felt compelled to increase the number of visas for highly-trained and technically skilled foreign nationals to meet the demand (Whitehurst, 2003).

The National Mathematics Advisory Panel (NMAP) Report (2008) cites concerns that are also far reaching about the United States’ ability to compete globally. This report exposes an American workforce that is ill-prepared, lacks sustainable technical independence, and discusses the negative impact this can have on America’s national security and quality of life (National Mathematics Advisory Panel, 2008).

As stated before, the lack of basic computational skills has not only a deleterious effect on our technology-based economy, but also dramatically restricts the individual’s ability to become a productive wage earner, thus limiting their career mobility. This deficit of skills has also been linked to the inequity and further widening of the educational achievement gap among cultural, gender and racial groups leading directly to limitations in future earnings and occupational opportunities (Loveless & Coughlan 2004). To put this in a more global context; if the majority of people in the labor force are mathematically limited, then the economy as a whole suffers.

Returning to a discussion of mathematical education: In 2000, the National Assessment of Educational Progress (NAEP) reported results of math scores continuing to decline, with 31% of fourth graders, 34% of eighth graders, and 35% of twelfth graders scoring below the basic level (Whitehurst, 2003). Eighth grade minority, and low socio-economic African American students, scored 68% below basic competency as compared to only 23% of white students (Whitehurst, 2003).
The NAEP also noted the achievement gap in math scores remains large and relatively unchanged between African American and white students, and between Hispanic and white students (Whitehurst, 2003). Several years of effort to improve school programs has generated some positive results, but not nearly to the degree desired. In 2007 NAEP showed only modest improvements for grades four and eight (Provasnik et al., 2012). In 2011, TIMSS (Trends in International Mathematics and Science Study) revealed that math achievement for fourth graders in the United States showed a modest increase of only 12 points since 2007 (Provasnik et al., 2012). Likewise, eighth grade scores saw no appreciable difference between scores in 2007 and 2011 (Provasnik et al., 2012).

Renaissance Learning, Inc. a K-12 educational assessment learning and analytics company, conducted a study showing most students in grades two through six score below recommended benchmarks, and a high number of students entering middle school do not show math fact automaticity (Renaissance Learning, 2012). The data further demonstrates only 42 percent of seventh graders have attained a level of automaticity in multiplication facts, with still less (fewer than a third) having shown automaticity in division facts (Renaissance Learning, 2012). With an insufficient degree of attention paid to math fact automaticity, it is safe to state that students, who are not proficient in math fact recall when leaving elementary school, will likely never master these skills (Cowen & Donlan, 2011; Renaissance Learning, 2012).

In the United States, student proficiency levels decline as students advance through the grades, with only 23% of students in the 12th grade considered proficient. By comparison, Lee, Grigg, and Dion, as cited in Renaissance Learning (2012), commented
that the highest-performing countries do not experience such a decline in the upper grades.

Compared to the large body of research revolving around the acquisition of reading skills, there is not a corresponding body of research concerning instruction in mathematics. This lack of data denies policymakers a sound pathway for policy making improvements to mathematical curriculum policy (Whitehurst, 2003).

Some reasons for this lack of achievement in mathematics, alluded to above, include: 1) lack of opportunities in professional development, and support for educators, especially at elementary and middle school levels, 2) an increasing reliance on calculators, as opposed to gaining rote skills as a foundation for competence at an early stage in the classroom, 3) changes due to the Constructivist mathematical reform of the 1990s (explained below), and 4) despite the desires of parents, teachers and mathematicians for necessary rigor in the mathematics curricula, students were found to be inadequately prepared (Whitehurst, 2003).

For many years those guiding mathematical reform, Constructivists and Traditionalists have been involved in an on-going philosophical tug-of-war over both concepts and techniques as to how mathematics should be taught (Whitehurst, 2003). The Constructivist math reform movement of the 1990s; based on the theories of Jean Piaget, saw wide acceptance in these years (Hudson et al., 2010). Previous practices required teachers in the United States to cover a large number of mathematical concepts with a concentrated focus on teaching rote math skills, as opposed to conceptual mathematical comprehension (Hudson et al., 2010). According to Constructivist thinking, current math
standards have moved away from emphasis on rote memorization, in favor of a foundation of conceptual thinking (Hudson et al., 2010).

Both the National Council of Teachers of Mathematics (NCTM) and the National Research Council (NRC) supported the Constructivist reform movement, rejecting the idea of mastering computational procedures and applying same to problem-solving (Hudson et al., 2010). Constructivists contended that learning should be intrinsically motivated and not motivated by extrinsic rewards, that math learning should be fun and not drudgery, and as math drills and rote practice are less enjoyable, children are less likely to learn (Hudson et al., 2010).

Hudson, Kadan, Lavin, and Vasquez (2010) also believes that children should be both allowed and encouraged to construct their own meaning toward an understanding of math principles, rather than being inactive participants of knowledge given them by others. The purpose of instruction, then, is to act only as an aid in guiding children to develop understanding while working with concrete, real-life situations, and not by learning and memorizing of math procedures and facts in isolation.

Reformers of the 1990s focused less on fluency when mastering math facts and procedures, and more on conceptual understanding. The intention was toward gaining capacity to apply that which was learned to real-life situations (Whitehurst, 2003). These theorists espoused the view that drills are an inefficient means of building fact fluency. Sam Strother of the Developing Mathematical Thinking Institute, writes,

The theory behind the drill-and-practice approach is actually born from a body of research predominantly conducted on animals and infants, not school children or adults trying to learn something as complex as mathematics. The basic hypothesis was that if students were exposed to facts over and over again, the information would bond in their minds and be retained. (Strother, 2010, p. 2)
Strother (2010) hypothesizes that students who possess a strong numerical memory may achieve success for some math facts, but this is the exception, not the rule, as most students do not have a strong numerical memory capacity.

Traditionalist critics of the above Constructivist pedagogy feel these reforms to mathematics ignore the foundational building blocks needed to aid in a student’s ability to correctly become creative problem solvers. These theorists have generally felt there was an over-generalization of the role of discovery and curiosity as being core principles in learning, understanding and applying mathematics.

Traditionalists feel, again in contrast to Constructivists, that the acquisition of mathematics did not need to be “discovered” to be effective and that discovery methods could compromise a child’s learning unless they had previously mastered the background and foundational knowledge needed to solve the problem (Whitehurst, 2003). An additional criticism is that Traditionalists feel that it may take some students more time to acquire knowledge through discovery, therefore making this strategy inefficient for some students. Traditionalist perspective contends that learning should be fun and interesting, as long as content is not compromised along the way (Whitehurst, 2003). A body of research exists that supports the view of Constructivists relative to conceptual understanding and how the use of math manipulatives and visuals can tie math tasks together (Whitehurst, 2003). Other studies have revealed that the understanding of mathematical concepts can be learned through a variety of pedagogical techniques, such as direct instruction, exposure to a variety of worked math problems and a deep practice on a wide variety of problems (Whitehurst, 2003).
The philosophical math tug-of-war continues to be waged and the emphasis on basic math fact mastery continues to be debated. Members of the National Math Advisory Panel (NMAP) (2008), Common Core State Standards (CCSS) (2010), and the National Council of Teachers of Mathematics (NCTM) (2006) are in agreement that mastery and automaticity of basic math facts is an essential skill. These authorities also believe that this should be considered a foundational basis for the attainment of higher level mathematical achievement. It is therefore recommended by them that schools provide for and encourage student math fact automaticity of addition and subtraction facts before students leave the third grade, with a mastery goal of multi-digit addition, subtraction, multiplication, and division calculations before leaving the fifth grade (Crawford, 2003; Stickney, Sharp, & Kenyon, 2012).

**Student Mathematical Learning**

Most mathematicians agree that students who are successful in developing a strong foundation of mathematical number sense are more adept at being able to distinguish variations in quantity and numerical representation. Gersten and Chard (as cited in Renaissance Learning, 2012) draw a parallel between the need for number sense comprehension as a necessary precursor for the achievement of higher-order math skills, as is phonemic awareness is foundational to reading (Renaissance Learning, 2012). Crawford (2003) quotes Logan in defining automaticity as, “The immediate, obligatory way we apprehend the world around us. It is the fluent, effortless manner in which we perform skilled behaviors” (Crawford, 2003, p. 2) If automaticity is considered to be a key component to overall math achievement, then it is important that we come to
understand automaticity, how it is attained, and what steps can be taken to aid in its acquisition.

Researchers and cognitive psychologists alike have indicated that the human brain has fixed limitations of brain attention and memory capacities needed for problem solving (Lehner & Schools, 2008; Woodward, 2006). By freeing up memory and attention limitations with automatic recall of parts of a task, we are then able to attend to more complex math tasks (Whitehurst, 2003). It has been demonstrated that students who struggle to recall less than 30 correct math facts per minute, typically struggle with more complex math skills and concepts. Conversely, students who reach automaticity at a rate of between 30- and 40-correct problems per minute are much more apt to be successful in mastering higher-order mathematical skills and concepts.

Two types of knowledge, declarative and procedural, show the need for firm conceptual understanding of mathematical number sense, and are essential for math fact automaticity to be achieved (Crawford, 2003). Declarative knowledge is described as the retrieval of a correct answer without any intervening thought process (Crawford, 2003). Pellegrino & Goldman (1987), cited in the research paper of Patty Lehner (Lehner & Schools, 2008) comment on the fact that the ability to move math fact recall capabilities into declarative knowledge not only quickens the basic math fact operations themselves, but also frees up the capacity of the working memory making it more accessible to handle more complex math tasks (Cowen, Richard & Donlan, 2011; Renaissance Learning, 2012).

Students who have not yet established a comprehensive bank of declarative knowledge must thus rely on procedural knowledge; methods and strategies used to
determine their answers for math problems, instead of more easily recalled answers from competence in automaticity. To demonstrate --when adding 4+9, students often use a common strategy called “counting on” which begins with the student stating the larger addend (9) and adding the lesser addend (4) on his or her fingers while reciting, “9, 10, 11, 12, 13” thus arriving at the correct answer. Use of procedural knowledge and strategies to ascertain correct answers can be used, but often requires increased effort, is more frequently prone to error, and interferes with the success of attaining higher-order math concepts (Crawford, 2003; Lehner & Schools, 2008).

With automaticity, students’ answers are generated more quickly and no longer dependent on procedural strategies, instead coming from direct retrieval, without need for conscious thought (Stickney, Sharp, & Kenyon, 2012).

According to Crawford, students move through the following three stages of learning that are determined as requirements for achieving automaticity in math facts (Crawford, 2003).

Stage One: The determining of answers to math facts. This beginning stage consists of the student’s ability to obtain procedural knowledge of math facts, often typically characterized by children’s counting on fingers, doing repetitive operations, or other kinds of strategies to arrive at a math fact (Crawford, 2003).

Stage Two: Using decomposition strategies for remembering math facts. At this stage the student works to develop the ability to accurately retrieve math facts, at the expense of slower speed. Students typically apply a strategy called “decomposition” where they use related facts or apply mathematical principles such as the commutative property and inverse operations to aid in problem solving (Crawford, 2003).
Stage Three: The development of automaticity. This final stage is acquisition of declarative knowledge, or “direct retrieval.” Learning at this critical stage is often referred to as mastery, automaticity, or overlearning (Crawford, 2003). It is at this level that students realize their capability of recalling easily answers to math facts, without relying on any other strategies for immediate retrieval of answers (Rave & Golightly, 2014). Once accuracy is established, the use of a timing component can further increase accuracy which ultimately facilitates automatic responses (Rave & Golightly, 2014). Typically, most students begin to move from predominantly procedural knowledge, to predominantly declarative knowledge in first and second grades, and are using a more sophisticated procedural retrieval method by the end of fifth grade (Cowan & Donlan, 2011; Crawford, 2003).

According to the National Math Panel Report (NMPR) (2008), in order for students to be adequately prepared to meet the higher-order mathematical challenges of Algebra, math curriculum must develop conceptual comprehension, fluency of computation, and skill-based problem-solving capabilities, as a concurrent activity. Whole number operations and fluency become integral and foundational for these students when given adequate and appropriate practice. This allows for the development of automatic retrieval of related addition, subtraction, multiplication, and division facts (National Math Panel Report, 2008). Cholmsky (2011) stated, “. . . conceptual understanding and fact fluency are mutually supportive, and should not be seen as competing for class time” (p. 3).
Acquisition of Math Fact Automaticity

Taking into consideration clearly differing philosophies and opinions on mathematical pedagogy, the importance of the need for students to achieve mastery and automaticity of basic math facts has come into controversy, and thus is now a hot topic under debate. To restate, there are many experts that agree that a student’s capacity to reach mastery and automaticity in the recall of basic math facts is a necessary and essential component in a student’s ability to achieve proficiency with higher-order math skill processes (Local News, n.d.). Similar to the differences of opinion of math theorists about math acquisition and pedagogy in general, it therefore comes as no surprise that there is considerable debate as to how math fact automaticity should be taught as well.

Constructionist theorists maintain that math analysis is the foundation of critical thinking skills, and should take precedence over rote memorization (Mahoney & Knowles, 2010). Mahoney & Knowles argue that since memorization is limited to only a short term storage pathway—a byproduct of the analytical process—rote procedures should not be employed.

Wittman, Marcinkiewicz and Hamodey (1998), hold an opposing view, that as early as 1899 it was reported that the automaticity of knowledge, brought about by repetitive practice was instrumental, not only for the acquisition and refinement of new skills, but was the foundation of mastery level performance. Though the above mentioned approaches are dissimilar, both believe and support the need for students to be able to clearly demonstrate math fact automaticity (Burns, Kanive, & DeGrande, 2012; Poncy, Duhon, Lee, & Key, 2010). The literature points to at least two specific approaches used by teachers when helping students develop automaticity: one of these is the use of
specific approaches and strategies for teaching facts; the other is the use of timed drills. Research indicates integrating both approaches would be most beneficial for students (Woodward, 2006).

More specifically, automaticity is attained when students are able to typically give a correct response to a basic math fact problem within two seconds (Frawley, 2012). This gain of math fact automaticity, at the elementary grade level, helps to increase math efficiency and effectiveness, thereby reducing student frustration and failure. This frustration leads to the following: Students who lack automaticity of basic facts by the end of fifth grade will most likely not be afforded adequate opportunities in the future to achieve automaticity, thereby further widening the achievement gap (Wong, & Evans, 2007). Thus the learning and automaticity of basic math facts either occurs in elementary school or not at all.

Unless importance is attached to the task, it is natural for a student to disregard the importance of learning a given skill. If this skill is to be sufficiently mastered, or even attempted, a student must first deem the task to be intrinsically necessary and beneficial. They must see this as crucial to their own success in life (Stickney, Sharp, & Kenyon, 2012). Secondly, for a student to be successful they must take ownership of fluency and mastery, recognizing that these do not occur automatically. It takes both time and effort, and an abundance of repetitious practice (Stickney, Sharp, & Kenyon, 2012).
The Teaching of Math Fact Strategies/Methodologies

In the United States, research has shown few education curricula providing adequate practice for ensuring quick and efficient recall of math facts, and therefore the ability to perform on standard algorithms (Renaissance Learning, 2012). The NMAP, commonly referred to as the National Math Panel, recognizes this curriculum gap, stating “. . . most schools provide supplemental means of practicing math facts, such as flash cards, worksheets, and computer software.” (Renaissance Learning, 2012, p. 3) This group points to the need for educators to be confident that all students are attaining automaticity by embedding practice within their regular mathematics program (Renaissance Learning, 2012). It is therefore, prudent for teachers to provide numerous practice opportunities, set individual student goals, and establish criteria based on rate and accuracy levels for achievement.

Researchers have shown increased repetition to be instrumental to gain greater recall and fluency. For students to reach the ability to retain answers, i.e. math facts, for a long period of time, additional and sustained practice following initial mastery, is necessary. The need for practice is further emphasized by Willingham (2009), as cited in a study by Renaissance Learning (2012). Math fact automaticity is gained through significant practice, with practice being the cornerstone to automaticity and achieved through a concentrated amount of effort.

In a 2002, a four week study of Renaissance Learning’s computerized math fact assessment software program--Accelerated Math Fluency--was shown to have a significant impact on basic math fact automaticity. This program embeds practice, and
thus, is in line with the above concept. Their study was comprehensive, involving approximately 1,500 students in grades one through five.

These students were first given a 1-minute pretest, to determine their appropriate math fact level, then participating in practice sessions with Accelerated Math Fluency software. These practice sessions included 40 assisted-response items in which students were to practice until achieving a goal of 100% accuracy in just two minutes. Then, students took a post-test.

Those students achieving 100% accuracy on the posttest, moved to the next higher math fact level. Students failing to meet the goal were allowed to continue practicing until such time as they were successful. Study results indicated that, on average, students at all grade levels (1-5) showed an improvement of 6.9 more correct responses. Students in 3rd-5th grades showed the most improvement of 8.4 correct responses (Renaissance Learning, 2002). By any measure, this is a significant improvement.

At a much more basic level, research has been performed on brain function, to explore moving math facts from short-term to long-term memory. Does this require a student to not simply ascertain a correct answer, but be able to retrieve it correctly on a consistent basis? Another research group, Scholastic Research (2012), in an article states that instruction and practice are the processes by which math fact retrieval moves from a quantitative area of the brain to an area related to automaticity.

Brain research by this group indicates that repetitious actions produce real physical alterations in the brain. This was found through the use of magnetic resonance imaging (MRI). Cognitive scientists have discovered, using this method, that there is an
actual shift in brain activation patterns as new and non-mastered math facts are learned (Fast et al., 2010).

This method of repeated actions shows a thickening of the myelin sheath that surrounds neurons in the brain, thus creating more “bandwidth” allowing for faster retrieval of information. Cognitive resources are then freed, becoming available for more complex math tasks, such as carrying and borrowing, and for self-monitoring mathematical abilities (Renaissance Learning, 2012).

Rave and Golightly (2014), based on the above research, believe students should be provided with a daily ten-minute period of time dedicated to the practice for fluency. Bystrom (2010) followed the same reasoning in her study, by stating that daily instruction should be provided using various strategies, activities or methods.

Options as to strategies and programs are available to help students develop math fact fluency: However, before deciding on which intervention to implement, careful consideration of choices must be taken into account. Since interventions vary, it can often be difficult to determine which of these would be the most effective. Effective intervention programs should: include repetitive actions and drills, use a variety of modalities (visual, auditory and kinesthetic) to accommodate different learning styles, target specific student needs, and lastly, introduce new mathematics skills in a systematic and incremental manner (Frawley, 2012).

Diverse interventions, such as flashcards, songs/raps, games and worksheets, are most commonly used intervention strategies by teachers. When considering implementation, teachers should carefully weigh the appropriateness and adequacy of the
given intervention to determine its effectiveness in meeting the needs of individual students (Poncy et al; Skinner, Pappas, & Davis, 2005).

As the desired automaticity becomes firmly established, on-going practice is important for reinforcement, as is the reviewing of this information. Some teachers are reticent to use math fact timed test approach with students, fearing a negative effect on student motivation. However, research has shown that timed tests actually have the opposite effect, that students: 1) like being timed, 2) like having the ability to challenge themselves through repeated practice and assessment, 3) and also like monitoring their own successes (Renaissance Learning, 2012).

Within the last decade, classroom use of computer software programs has become much more prevalent in the school setting. Current research data shows that many computer-based intervention programs increase math skills for both students with learning disabilities as well as students not so affected (Burns et al., 2012; Carr, Taasoobshirazi, Stroud, & Rover, 2011; Tienken & Wilson, 2007; Wong & Evans, 2007).

It has also been shown that students using computers, as part of their instructional program, typically advance more quickly and in less time, and retain learned material for greater periods of time (Wong & Evans, 2007). Providing students using computers with opportunities to practice offers advantages in contrast with more traditional methodologies and strategies. Practice using computer programs allows students to: 1) . . . make individual progress at their own pace, 2) . . . practice using both horizontal and vertical types of problems, 3) . . . receive and take ownership of their achievement based on feedback, and 4) . . . use progress-monitoring that is immediate and automatic (Wong & Evans, 2007).
A study by Hudson, Kadan, Lavin, and Vasquez (2010) found, that students in the fourth, fifth, sixth, and ninth grades, using technology to improve fact fluency, realized an improvement in understanding basic math skills. Test scores that were post-intervention indicate that students were more likely to show increased achievement in mathematical competency, with scores of 70 percent or higher, when compared to pre-assessment scores (Hudson, Kadan, Lavin, & Vasquez, 2010).

For the above reasons, the National Math Panel (2008) recommends the use of properly designed computer-assisted instruction (CAI) drill-and-practice software of high-quality and that are implemented with fidelity. Research of effective computer-based programs has shown to aid the student in freeing up working memory for complicated and complex math tasks NMPA (2008).

Effect of Automaticity on Student Test Scores

Research (e.g., Knowles, 2010) in this area is sparse, and what research has been done generally centers on students with learning disabilities, and therefore cannot be easily generalized to the general education student. A study by Tienken and Wilson (2007) also found the use of computer assisted instruction (CAI) programs to have a positive effect (although slight) on student mastery of basic math skills. The Accelerated Math Fluency program, designed by Renaissance Learning, Inc. was incorporated in a large-scale peer-reviewed study, and found by this study to be a useful educational tool. This intervention aided all students in the study in the mastery and achievement of math fact automaticity. This study therefore leads to the suggestion that while practice is beneficial for all students, it was especially so for low-achieving students who may then
be able to break the cycle of falling further behind their peers (Renaissance Learning, 2014).

The study by Renaissance Learning (2014) also examined how math fact mastery was linked to the relationship between automaticity, and increases in general math achievement. This study revealed, significantly, that most students were not meeting grade-level math fact mastery standards, as set by the NMAP and the CCSS Initiative; but those students who had achieved automaticity were more likely to make greater gains in mathematics achievement (Renaissance Learning, 2014).

As stated by Stickney, Sharp, and Kenyon (2012) and quoted in a study commissioned by Renaissance Learning, Inc. in 2014, “Teachers can feel confident that using tools such as Accelerated Math Fluency to build math fact automaticity can contribute significantly to improved general mathematics achievement” (Renaissance Learning, 2014, p. 3). Thus the case is made that this intervention may well be one of the better interventions available to teachers.

**Summary**

The present study drew upon the above research to look at a local implementation of Accelerated Math Fluency, a computer aided modality, in a general education setting. The study design included a control and experimental group for the purpose of comparing the modern/technical and the older/traditional modalities.
CHAPTER III

METHODOLOGY

Student proficiency in math has become instrumental to economic success globally, nationally, and personally. “The need for higher levels of math competence has increased in this technology-based world, and a lack of knowledge, understanding, and skill development can close doors for students,” stated researchers, Axtell, McCallum, Mee Bell, and Poncy (as cited in Bystrom, 2010). Many experts agree that reaching automaticity in the recall of basic math facts is a necessary component in a student’s ability to attain complex higher-order math skills and problem-solving tasks (Wong & Evans, 2007).

The purpose of the present study was to compare math achievement of students who utilized Accelerated Math Fluency, to the achievement of students who were not exposed to this intervention, as a way to test the hypothesis that the intervention is more effective than traditional classroom approaches and is related to higher math achievement scores.

The intervention studied, Accelerated Math Fluency, is a computer software program that provides all students practice and assessment on basic math facts.
Description of Experimental and Control Groups

This study employed a quasi-experimental design in which two groups of students were closely matched to form the experimental and control groups. This study was comprised of students attending two different school sites within the same school district, located in a medium-sized city in northern California.

A design was developed utilizing these schools to explore the question of the effectiveness of the chosen intervention. One was, in effect, an experimental group, utilizing Accelerated Math Fluency, while the other was the control and did not have access to the intervention.

The experimental group consisted of 56 students, while the control class consisted of 83 students. Students in the experimental group were assigned to two sixth grade teachers in self-contained classrooms, whereas the control group was assigned to a single math teacher with students being assigned to one of three rotational class periods. The school sites were demographically comparable. See Table 1.

Specifically, both the experimental and the control groups of sixth graders were demographically comparable as presented in Table 2.

Description of the Intervention

Renaissance Learning’s Accelerated Math Fluency program was chosen as an aide for student attainment of math fact automaticity and math fact fluency. This intervention was chosen as a means to improve overall math scores, for grades two through six, at the school designated as the experimental group.
Table 1

2012-13 School Site

<table>
<thead>
<tr>
<th>School site demographics</th>
<th>Experimental group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Student Enrollment</td>
<td>434</td>
<td>610</td>
</tr>
<tr>
<td>Free/Reduced School Lunch</td>
<td>55.8%</td>
<td>64.8%</td>
</tr>
<tr>
<td>Socioeconomic Disadvantaged</td>
<td>62.3%</td>
<td>67.6%</td>
</tr>
<tr>
<td>English Language Learners</td>
<td>4.4%</td>
<td>9.2%</td>
</tr>
<tr>
<td>Students with Disabilities</td>
<td>15.6%</td>
<td>14.9%</td>
</tr>
</tbody>
</table>


Table 2

2012-13 Sixth Grade Student Group Demographics

<table>
<thead>
<tr>
<th>Sixth grade student groups</th>
<th>Experimental group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sixth Grade Student Population</td>
<td>56</td>
<td>83</td>
</tr>
<tr>
<td>Socially Economically Disadvantaged</td>
<td>62.3%</td>
<td>67.6%</td>
</tr>
<tr>
<td>English Language Learners</td>
<td>4.4%</td>
<td>9.2%</td>
</tr>
</tbody>
</table>

The Accelerated Math Fluency program is designed to provide intense computer-based practice for math fact automaticity and fluency through the use of a database of mathematical problems broken into 71 math fact levels encompassing addition, subtraction, multiplication, division, fractions, and decimals and percents. As a result of evidence-based research, commissioned by Renaissance Learning, Inc. and involving some 400,000 students across the nation during the 2009-2010 school year, the 71 math facts levels mentioned above were then grouped into grade-level specific mastery benchmarks. These grade-level benchmarks are as follows in Table 3.

Table 3

*Accelerated Math Fluency Grade-Level Benchmark Goals*

<table>
<thead>
<tr>
<th>Mathematical operation</th>
<th>Grade-level benchmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addition</td>
<td>2nd Grade</td>
</tr>
<tr>
<td>Subtraction</td>
<td>3rd Grade</td>
</tr>
<tr>
<td>Multiplication</td>
<td>4th Grade</td>
</tr>
<tr>
<td>Division</td>
<td>5th Grade</td>
</tr>
<tr>
<td>Squares, Fractions/Decimals/Percentages, and Conversions</td>
<td>6-12th Grades</td>
</tr>
</tbody>
</table>

Their study resulted in the determination of a minimum response time of two minutes or less, with 100% accuracy on a forty-item test, as being a reasonable mastery goal for the elementary students studied. Renaissance Learning’s research also suggests students participate in practicing and testing math facts using this intervention daily, for
15-minute periods of time, three times per week, in order to attain maximum growth in automaticity. Teachers implementing this intervention have the capability of re-ordering and assigning math fact levels to best meet the needs of their students.

Students begin using the intervention by completing a forty-item timed test to determine a math fact baseline level. If completed with 100% accuracy within the 2-minute time limit, students progress to the next designated level. As students master subsequent math fact levels the intervention software automatically moves them to the next higher level where the practice and testing cycle begins again. This cycle continues until students have mastered all assigned levels for their grade-level benchmark. When a student masters all assigned levels they may then go back and try to improve their previous mastery time for already mastered math fact levels.

Teachers observe student achievement through the use of progress-monitoring tools embedded within the program. The program can be modified and individualized to help struggling students by assigning appropriate math fact levels, provide help in the form of software generated worksheets and/or flashcards and teacher feedback specific to the student’s current math fact level. While not being able to test, all students have access to the Accelerated Math Fluency program at home in order to continue practicing.

In this study, the experimental group used Accelerated Math Fluency daily for 15-minutes, while the control group did not use Accelerated Math Fluency. The protocols for implementing Accelerated Math Fluency were met with fidelity and students were closely monitored by the teacher. Students were required by the teacher to successfully complete five practice sessions, before attempting a timed test. Depending on the outcome of a test, students either automatically advanced to the next level or were
required to continue practicing before attempting to test again. The teacher tracked
student data daily through the Accelerated Math Fluency progress-monitoring software as
students practiced and moved from one level to another. Classroom incentive programs
were put in place by the teacher to encourage attainment of both classroom and individual
student goals.

Students in both the experimental and control groups were taught by teachers
with approximately the same number of years (6) experience teaching sixth grade
mathematics. The teacher of the experimental participated in a Accelerated Math Fluency
three-year training program. The control group did not have a classroom basic math fact
automaticity intervention program incorporated as part of their daily mathematics
curriculum and instructional practices.

Measurements

For the purpose of comparative evaluation between both the experimental
group and control group, this study collected and analyzed 2013 California Standards
Test (CST) for Mathematics test scores. This test is one of the annual standardized tests
administered each spring as a component of the Standardized Testing and Reporting
(STAR) Program set by the California State Board of Education. The sixth grade math
CST assessment consisted of 65 test items covering five content areas: 1) number sense,
2) algebra and functions, 3) measurement and geometry, 4) mathematical reasoning, and
5) statistics, data analysis, and probability. Individual student scale scores (150-600) are
used by California to categorize students into one of five math proficiency levels: 1) far
below basic, 2) below basic, 3) basic, 4) proficient, and 5) advanced.
Collection of Data

Student mathematics achievement scores for analysis for this study were collected from the school district student information system. Annual achievement test data for all academic content areas, including English language arts, mathematics, social studies and science was available for analysis. This researcher requested the 2013 mathematical achievement test data for all students in both the experimental and control groups. Analysis was primarily conducted using the online scientific software program, Graphpad QuickCalcs (2015), by comparing the group averages of the experimental and control groups using a two-sample t-Test to determine if a difference between groups was significant at the $p < .05$ level.

This study investigated the change in math fact automaticity over three years, and over multiple grade levels at the experimental school using data collected with math fact benchmark tests. Additional qualitative information was reported, based on teacher observations of student responses using the Accelerated Math Fluency program at the experimental school and shared at teacher implementation meetings.
CHAPTER IV

FINDINGS AND RESULTS

This study was undertaken to determine if math fact automaticity, achieved through deep practice and the use of a computer-based practice and assessment program, would result in elementary students achieving higher levels of math automaticity and higher math achievement for two groups of sixth graders. A quasi-experimental design involving two groups of closely matched sixth graders, one experimental and one control, was used to determine if any significant difference in mathematics achievement would be realized by the experimental group that used the computer-based program, Accelerated Math Fluency, on a daily basis. The comparison between groups was based on student scores on the annual state mathematics achievement test, the California Standards Test.

Results are in effect a two-stage process: 1) Student data was derived from a district information system on which a $t$-Test was conducted and 2) Teacher observations were collected as anecdotal data on student performance.

Objective Data

A $t$-Test was conducted using district data from the California Standards Test (CST) for 2013 using the online scientific software program, QuickCalcs (2015). Analysis of the outcomes of the $t$-Test, as illustrated in Table 4, showed no statistically
Table 4

_t-Test Results Comparing Experimental and Control Groups on 2013 CST_

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Experimental group</th>
<th>Control group</th>
<th>95% CI for Mean Difference</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( M ) ( SD ) ( n )</td>
<td>( M ) ( SD ) ( n )</td>
<td>t</td>
<td></td>
</tr>
<tr>
<td></td>
<td>362.63 55.27 56</td>
<td>356.85 57.89 80</td>
<td>0.5833</td>
<td>-13.81 to 25.36</td>
</tr>
</tbody>
</table>

Note. \( p < .05 \). _t_-Test results show a \( p \) value of 0.561, not statistically significant.

significant difference between the sample mean of the experimental group (362.63) and the control group (356.85).

Teacher Reported Observations

This researcher is including below observations of the experimental class--incorporating Accelerated Math Fluency--as a supplement to the above objective data.

Students took ownership and responsibility for their learning by monitoring their own progress, setting personal goals and seeking help when needed, without teacher prompting. Students who mastered all levels at the initial rate went back and wanted to better their previous times. Teacher observations also included:

- An increase in student participation in classroom instruction and activities.
- As students progressed, fewer and fewer relied on strategies such as counting on their fingers or “skip-counting”.
- Student persistence and perseverance increased, math frustration levels decreased, and students were actively engaged and motivated.
- Increased student confidence was seen by both teacher and student in student's own math capabilities.

The Accelerated Math Fluency program was used by all students in grades two through six at the experimental school. There is no growth data for the control group as they did not use the Accelerated Math Fluency intervention program. Figure 1 demonstrates an increase in student achievement for students in the experimental school, in the targeted grades, using Accelerated Math Fluency over a three-year period.

![Graph showing percentage of students meeting grade-level benchmarks](image)

**Figure 1.** Experimental school-wide percentages of students meeting grade-level benchmarks.


Table 5 demonstrates student achievement of math fact automaticity for students in grades two through six at the school serving as experimental. This data was gathered over a three-year period.
As seen in Table 5, significant growth in the percentage of students meeting grade-level benchmarks occurred not only over the three-year time period, but also across all grade levels using the Accelerated Math Fluency program. The data illustrates substantial growth for all grade levels over the three-year period as teachers continued to implement the program each year with increased fidelity and consistency by embedding, in their daily math program, a fifteen-minute block of time for practice and the students’ ability to self-assess their own progress.

Table 5

| Percent of Students at the Experimental School Meeting Math Fact Benchmarks |
|-------------------------------|-----------------|-----------------|-----------------|
| School Year | 2011-2012 | 2012-2013 | 2013-2014 |
| 2nd Grade | 27% | 89% | 95% |
| 3rd Grade | 11% | 46% | 88% |
| 4th Grade | 12% | 73% | 81% |
| 5th Grade | 25% | 76% | 89% |
| 6th Grade | 57% | 78% | 85% |


Though the *t*-Test showed no statistically significant difference between control and experimental groups, the data presented in both Figure 1 and Table 5 suggest that students using Accelerated Math Fluency program can indeed improve their basic math fact automaticity.
Students in the experimental group, using the Accelerated Math Fluency intervention, demonstrated gains in automaticity over a three-year period from 2011-2014. Table 6 illustrates both: 1) average percent of growth over time for cohorts of students moving from one grade level to the next, and 2) growth over time, horizontally, for each grade-level.

Table 6

*Experimental Group - Percent of Students Meeting Grade-Level Benchmark*

<table>
<thead>
<tr>
<th>School year</th>
<th>2011-2012</th>
<th>2012-2013</th>
<th>2013-2014</th>
<th>Average three-year growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd Grade</td>
<td>27%</td>
<td>89%</td>
<td>95%</td>
<td></td>
</tr>
<tr>
<td>3rd Grade</td>
<td>11%</td>
<td>46%</td>
<td>88%</td>
<td></td>
</tr>
<tr>
<td>4th Grade</td>
<td>12%</td>
<td>73%</td>
<td>81%</td>
<td>27%</td>
</tr>
<tr>
<td>5th Grade</td>
<td>25%</td>
<td>76%</td>
<td>89%</td>
<td>39%</td>
</tr>
<tr>
<td>6th Grade</td>
<td>57%</td>
<td>78%</td>
<td>85%</td>
<td>37%</td>
</tr>
</tbody>
</table>

* This is a two-year growth rate for 5th graders

Figure 2 clearly shows growth by grade across a three-year span. This data, along with researcher observations, suggests the following: 1) over time teachers implemented the intervention with increased fidelity, 2) students became increasingly familiar with the program, 3) students became more confident and competent using technology devices, and 4) students appeared to be more fully engaged and motivated to participate in the intervention.
Figure 2. Graph demonstrates same student progress for a three-year period.
CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

This investigation looked into the hypothesis that automaticity of basic math facts had an impact on the overall achievement of sixth grade students in mathematics. Secondly, the study was conducted to determine if math fact automaticity, achieved through the use of a computerized math fact intervention program, Accelerated Math Fluency, could encourage results for elementary students gaining higher levels of math automaticity and higher math achievement test scores.

Two groups of sixth grade students were compared, with one class serving as the experimental group—utilizing Renaissance Learning’s Accelerated Math Fluency program; the other class, serving as control, thus having no intervention. A comparison of the two groups, utilizing a two-sample Test, showed no statistically significant difference in math scores between the two groups on the 2013 California Standardized Test for mathematics.

Conclusions

The present study does not exactly replicate the 2002 study by Renaissance Learning however; it also attempted to look at growth in math fact automaticity across
years and across grade-levels at the experimental school. Assuming the possibility of a
difference between classrooms serving as experimental and control groups, suggestions
are made toward exploring ways of improving the significance. As this researcher has
confidence in the efficacy of this program, therefore will make suggestions below which
hopefully will be considered by individuals in this area.

As an introduction to recommendations made below, a further look at the
Renaissance Learning, Inc., Accelerated Math Fluency intervention approach follows.

Research by Renaissance Learning, Inc., Accelerated Math Fluency
intervention and by others found that math fact automaticity is beneficial to student
achievement in regards to successful learning of higher-order math concepts. In 2002,
Renaissance Learning, Inc. reported a statistically significant impact on basic math fact
automaticity in a four-week long study of the effectiveness of the Accelerated Math
Fluency program. This study was large, involving approximately 1,500 students in grades
one through five.

Recommendations for Further Research

This researcher suggests that for results to be meaningful, a more extensive
study should be conducted. This projected study would consist of a larger pool of
students, from multiple schools, grades two-eight. Another aspect of this study would be
to run the study longitudinally, perhaps over a five or six years to determine if math fact
automaticity can in fact demonstrate long term effects across this time span. It would be
of interest to investigate and analyze the types of math courses taken at the secondary
level, and evidence of math achievement, by those students having used the Accelerated
Math Fluency intervention during elementary school.

Other questions to further examine the effects of Accelerated Math Fluency might include: 1) by attaining math fact automaticity in elementary school would girls
gain confidence in their mathematical capabilities and self-efficacy to be interested,
engaged and successful in mathematics at the secondary school level, 2) could this
intervention provide for significant growth and achievement of English language
learners, students of low socioeconomic status and students of culture, race and gender, in
order to help bridge the achievement gap, 3) is Accelerated Math Fluency an effective
intervention program for students with learning disabilities, and 4) is this intervention
worth the cost for schools and districts with tight financial restraints?

Using multiple measures of mathematics achievement is the next
recommendation. This present study relied solely on a single measure for analysis. This
researcher would like to know if using multiple math achievement measures, perhaps in
the form of: paper and pencil timed tests, on-demand quizzes, oral response quizzes and
assessments would provide more conclusive measures of math fact mastery and
automaticity.

Attitudinal Based Recommendations

First it is recommended that attitudinal or anecdotal surveys and/or
interviews—both of teachers and students—be conducted to compliment the database of
actual test-based performance. Teachers could be surveyed about their personal attitudes,
capabilities and confidence levels in teaching math and the influences those may have on
their students. What about a teacher’s philosophical stance on providing time during the class day for deep practice, is it perceived as valuable or considered to negatively impact the limited time constraints of the classroom? How open and willing is a teacher to embrace change to their teaching practice, and does the length of a teacher’s career play a role in whether or not they may be willing to change.

Students, by contrast, could be given surveys asking, for example, how many math facts can be performed by them in a set interval. Personal items might also be included such as, “How do you feel about your math performance?” or “Do you enjoy using the Accelerated Math Fluency intervention?” Ask students if they feel more successful in math as a result of the intervention, whether they find value in the program, and what level of frustration they experience during math class.

This researcher further recommends looking at still other types of interventions and strategies, to both contrast and compliment use of Accelerated Math Fluency. Other such approaches could include the effectiveness of using flashcards, songs, games, peer tutors, pencil and paper timed tests, practicing with math manipulatives and other computer software programs.

The ensuing results would hopefully be useful to teachers, schools, and districts in determining the most effective and efficient types of interventions for meeting the needs of their students. This researcher recognizes difficulties in implementing the above, in the form of financial and time constraints, variations in teacher training, and ever-changing educational and political challenges districts are confronted with. This said, the stakes are too high to leave these possibilities unexplored.
REFERENCES


