2012-11-16

Learning Within a Computer-Assisted Instructional Environment: Effects on Multiplication Math Fact Mastery and Self-Efficacy in Elementary-Age Students

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A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Arts

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November 2012

ABSTRACT

Learning Within a Computer-Assisted Instructional Environment: Effects on Multiplication Math Fact Mastery and Self-Efficacy in Elementary-Age Students

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The primary purpose of this study was to evaluate the effect of basic multiplication mastery (0-12) and self-efficacy outcomes for elementary age students attempting to master multiplication facts in a Computer-Assisted Instructional (CAI) environment. Timez Attack (TA), a modern Internet based 3-D multiplication video game, was the computer program used in this study. Four third- and four fourth-grade classes of students at a public charter school received either 12 20-minute Teacher-Led Instructional (TLI), or TA multiplication practice sessions. Pre- and post Math Attitude Survey (MAS), timed multiplication tests, observations, and informal interviews were used to assess and compare TA and TLI's learning environments, performance, and self-efficacy outcomes. Both third- and fourth-grade TA students' level of multiplication mastery improved significantly after intervention. Results from the post-MAS also revealed significantly higher self-efficacy beliefs, and reduced nervousness in learning multiplication facts amongst some TA students. Statistical data analysis revealed no significant performance outcome differences between TLI and TA third-grade classes; however, post-test comparisons between fourth-grade TLI and TA students showed TA students significantly outperforming their comparison group counterparts by answering approximately 50% more problems in a given time and feeling significantly less nervous toward learning new multiplication math facts. The TA program's motivational, self-paced, and self-evaluative features seemed to produce a positive learning environment, which encouraged student learning. Educators should consider using CAI with features similar to TA's to improve students' academic performance and self-efficacy.

Keywords: multiplication, automaticity, mastery, self-efficacy, education, computer-assisted instruction, elementary mathematics, educational video games

ACKNOWLEDGMENTS

It has been a privilege and honor over the past four years to both learn from and work with many amazing faculty, staff and fellow graduate students. I want to especially thank Dr. Douglas Corey, my chair, for his patience in my choosing a research focus and sharing his statistical expertise with me. You were the right chair for the job! I would also like to thank Dr. Keith Leatham for not providing the answers to all my research questions, teaching me instead how to search out and discover solutions to problems on my own. This is a valuable skill, not only in research but life in general, which I am trying to pass on to my own students. Dr. Richard West thanks for providing our class with the project idea that was the springboard for my whole thesis. This would never have come to pass without you. I am also appreciative of Kathy Lee for keeping me on track with my graduation requirements. I am grateful for all of my fellow graduate study partners and their patience with me as I tried to retrieve past mathematical knowledge that had been stored in my memory for longer than most of you have been alive! I especially want to thank Heather Ambler Williams, for being more than just an "office mate" but my dear friend, tutor, cheerleader, research assistant, "technology consultant" and now my co-worker. Go ALA!

To my loving husband, Carl Hanson, whose encouragement and example of hard work kept me going when I wanted to give up (every semester!). Thanks for teaching your children and me that "Hanson's" can do hard things. I love you. To my children, Brooke, Spencer, Madison, and Nate, my son-in-law Deven and granddaughter Poppy, thanks for being forgiving as I often temporarily abandoned my mother and grandmother duties to fulfill my graduate student duties. Although it may not have seemed like it at times, all of you are truly what is most important to me. To my father and mother-in-law Ed and Nancy Hanson, thanks for accepting

me into your family and being every bit as proud of my accomplishments as your very own children's, and providing me with the extra encouragement I have needed over the past four years. To Stephanie and Al we are so glad that you are a part of our family, thanks for your spreadsheet expertise and data entry skills. Thanks also to all of my dear friends and other family members, for your love and support, especially Laure Decker for providing me with a quiet "study hideaway" in her guestroom when I needed it.

I would like to give a special thanks to the administration, faculty, and staff at American Leadership Academy for helping me with my data collection. You're an impressive educational team.

Finally, to my deceased parents, Afton and Reid Jones, thanks for providing me with the knowledge that with hard work, prayer, and faith in the Lord I can accomplish those things I set out to do. I love and miss you.

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CHAPTER I: INTRODUCTION

According to the national mathematics standards set by the National Council of Teachers of Mathematics (NCTM) (2010), third- to fifth-grade students need to develop multiplication fluency. Additionally, the National Research Council (2001) has stated that students need to develop procedural fluency, which they defined as having the necessary skills to carry out mathematical procedures (like multiplication) flexibly, accurately, efficiently, and appropriately. The National Mathematics Advisory Panel (2008) has recommended in their report "Foundations for Success: The Final Report of the National Mathematics Advisory Panel" that along with conceptual understanding and problem-solving, it is vital for students to develop abilities like mastery of basic multiplication facts, which are foundational to obtaining procedural fluency. The Panel also stated that students should experience conceptual understanding, problem-solving, and procedural fluency simultaneously because they are mutually supportive and facilitate the learning of each other.

Mastery (also referred to as automaticity) of basic multiplication facts (0-12), is commonly referred to as the effortless, accurate, and quick multiplication computation performance freeing up students' working memory, allowing them to focus on more complicated mathematical tasks (National Mathematics Advisory Panel, 2008). Multiplication mastery is a basic skill that helps students attain procedural fluency in many areas (Ashcraft, 1994). Research has suggested that multiplication mastery of basic facts is a lower-order component across many domains of mathematics. Without mastery in multiplication facts, students' working memory may be used on this basic skill rather than the task at hand, and higher-order processing is likely to be hindered (Ashcraft, 1994). Metaphorically speaking, one cannot understand or converse in a language one does not know. Students who have mastered the language of basic multiplication are better equipped with one of the necessary tools required in order to develop procedural fluency and perform higher mathematics requiring basic multiplication skills such as mental calculations, estimation, fractions, factoring algebraic equations, multi-digit multiplication, division, and understanding decimals and ratios (National Research Council, 2001; Elkins, 2002; Woodward, 2006).

Realizing some of the mathematical advantages connected to mastery of basic multiplication facts, it is not surprising that the learning of multiplication facts 0-12 constitutes a fundamental portion of U.S. elementary students' anticipated mathematical knowledge and understanding. Students throughout the U.S. spend much of their third grade year initially learning their basic multiplication facts and continue to review them in their upper elementary grades (NCTM, 2010; Jones, 2011). Despite this expectation, some studies have revealed that many U.S. students never attain mastery of single digit multiplication facts. (National Mathematics Advisory Panel, 2008; DeMaioribus, 2011). Furthermore, recent comparison studies between U.S. children and children in other nations have shown that contemporary U.S. elementary age children are slower and less efficient in solving problems involving single digit and whole number multiplication than students from countries with higher mathematics achievement scores. (Mullis, Martin, & Foy, 2008). As a result, U.S. students also execute more complex mathematical tasks involving multiplication less fluently and accurately than those students from countries with higher mathematical achievement (National Mathematics Advisory Panel, 2008). Results from the Trends in the International Mathematics and Science Study (TIMSS) conducted in 2007 revealed that only 10% of U.S. fourth-graders were able to solve more advanced complex mathematical problems when compared to 41% of fourth-graders in Singapore. Students in Singapore are international leaders in mathematical achievement and proved to be faster and more efficient in solving single digit and whole number multiplication problems than U.S. students (National Mathematics Advisory Panel, 2008; Mullis, et al., 2008).

Educational researchers have suggested investigating the use of computer-assisted instruction (CAI), which allows for individualization and extra practice as a tool in helping all students achieve multiplication mastery (Irish, 2002; Bouck, Bassette,Taber-Daughty,Flanagan, & Szwed, 2009). Mathematical CAI has been defined as technology-mediated computer software programs used for mathematical teaching and learning, drill-and practice, tutorial, and simulation activities offered either by themselves or as supplements to traditional, teacher-led instruction (TLI) (Moss, 2004). According to the NCTM (2000), technology provides teachers the ability to more easily adapt instruction to meet individual student needs. The National Mathematics Advisory Panel (2008) has also recommended that educators consider high quality, well-designed and implemented CAI programs incorporating drill and practice "as a useful tool" (p.51) in developing students' computational automaticity.

Some educational researchers have also suggested that use of mathematical CAI should be explored because it can potentially produce a learning environment that not only positively impacts students' mathematical skills, but also improves students' mathematical attitudes, including attitudes affecting mathematics self-efficacy beliefs (Bouck et al., 2009; Wittman, Marcinkiewicz, & Hamodey-Douglas, 1998; Moss, 2004; Cognition and Technology Group at Vanderbilt, 1992; Kulik, 2003; Kebritchi, Hirumi, & Bai, 2010). According to Bandura (1997), academic self-efficacy is one's belief in one's ability to succeed in a specific academic situation. A variety of research has indicated that students' mathematics self-efficacy is a strong predictor of mathematical performance (Bandura, 1986; Pajares, 1999; Pajares and Kranzler 1995; Pajares and Miller, 1994; Schunk, 1991). Pajares and Kranzler (1995) have stated that mathematical self-efficacy and general mental capacities can, at times, even affect mathematical performance equally. Pajares (1999) also stated that students with high mathematical self-efficacy showed greater accuracy and persistence when solving mathematical problems than those with low mathematical self-efficacy.

As computers have become more commonplace in school settings, mathematical CAI research, including investigations into the effect that CAI can have on students' multiplication mastery and attitudes, has expanded; however, due to continual developments in technology, much of the past multiplication CAI research involved outdated programs no longer in use or production. Wong and Evans (2007) stated, "due to the advances in computer technology and increased access of students to computers" (p. 6) more up-to-date comparisons between multiplication mastery through CAI and other strategies are needed. Furthermore, some past multiplication CAI research has reported conflicting findings. This may be due to rapid changes in technology, the variety of CAI programs, lack of a consistent framework with which to judge effective CAI software, and the size of study pools. Therefore, mathematics educational researchers throughout the past decade have continually called for an increased attention to better theory-driven studies investigating CAI features that most help improve students' mathematical attitudes and ability (Bouck et al., 2009; Stokes, 2008).

The primary purpose of this study was to evaluate multiplication mastery and self-efficacy outcomes on third- and fourth-grade elementary age students as they attempted to master multiplication facts in potentially engaging, self-evaluative, self-paced settings produced through the use of CAI video game play. This study also compared multiplication mastery and self-efficacy beliefs between students receiving CAI and those learning in more traditional TLI environments. Timez Attack (TA) (Version 5.29), a 3D Internet based computer multiplication video game developed by Big Brainz Incorporated, which was designed to help students at varying academic levels both understand and master basic multiplication facts, was chosen as the software for use in this study. Results from this study will hopefully not only add information regarding the effects that learning through CAI can have on basic multiplication mastery and self-efficacy, but will also add useful theoretical insights into the specific features of CAI software programs that can help create a positive and successful academic learning environment.

CHAPTER II: THEORETICAL FRAMEWORK

The three theoretical constructs central to my study and used in the framing of TA's instructional environment included effective CAI software program features, multiplication mastery, and self-efficacy. This framework provides a mapping of the relationships between all three of these theoretical constructs.

Effective CAI Software Program Features

CAI research findings have suggested at least four computer software features that are important components in producing a successful learning environment for improving students' academic performance and attitudinal beliefs. Three of these CAI software features included providing sufficient opportunities to respond, self-evaluative features with contingent and frequent feedback, and having the CAI linked to teacher instruction (Wilson, Majsterk & Simmons, 1996). Additionally, a fourth dimension which other research has shown to increase the effectiveness of CAI, includes the software's ability to engage and motivate students to put forth the effort to learn. (Kebritchi et al., 2010; Cognition and Technology Group at Vanderbilt, 1992). Explorations of TA game play provided some evidence of all four of the above described software features, and thus made TA a suitable program for use in this study. A detailed description of TA's software features can be found in the Methodology section.

Multiplication Mastery

As discussed earlier, multiplication mastery refers to the effortless, accurate, and quick computation of basic multiplication facts, which frees up working memory. According to some multiplication mastery researchers, students are considered to have achieved multiplication mastery when they correctly answer close to 40 basic math facts in one minute (Howell and Nolet, 2000; Shapir, 1989; DeMaioribus, 2011). There is some variability in this measurement.

Fact tests that included 0s and 1s or tested a single group of facts where each problem has a common multiplicand (i.e. just the fours or just the fives) would be easier than mixed fact tests or tests not including 0s and 1s. At the school where my study was conducted a measurement of 90 correct responses in three minutes (1 problem per 2 seconds) on 100-item tests was a typical measurement for mastery. When first learning new facts teachers sometimes allowed students five minutes on a 100-item test and then gradually reduced the time to three minutes. Although teachers at the school primarily tested for mastery using single fact tests, this same standard was used for both mixed and single fact tests and tests that did and did not included 1s and 0s. TA used 2 seconds per fact plus input speed (1.75 seconds for a single digit response and an additional .6 for each additional digit) when testing for mastery. As was typical in other multiplication research (Wong and Evans, 2007; Bouck et. al., 2009; Irish, 2000; Williams, 2000; Wilson, 1996) my study did not attempt to measure mastery with a particular response speed, but instead looked for any changes in students' accuracy and speed after intervention.

According to Wong and Evans (2007), "prior to engaging students in any program for improving the mastery of basic multiplication facts, their current level of proficiency needs to be established" (p. 92). Giving students a timed pre-test of multiplication math facts can do this. In my study identical 2-10s 100-item timed multiplication pre- and post-tests were used to assess the affect that TA might have on mastery levels by considering students' overall changes in number of correct responses from pre- to post-tests. A 2-10s test was chosen because TA began at the two's level, and the teachers involved in the study felt the overall time of study sessions would not allow for students to learn or review facts past their 10s.

Self-Efficacy

Bandura's (1997) definition of self-efficacy included the belief in one's effectiveness in performing specific tasks. He also stated that one's perceived self-efficacy can influence every aspect of an individual's life, including educational experiences. Social cognitive theorists who influenced this definition of self-efficacy hypothesized that interaction between environmental situations (including observational modeling), behaviors, and personal factors (such as thoughts or beliefs) have a prominent defining impact on human achievement. Bandura (1997) purported that there are four major factors that influence a person's academic self-efficacy: (1) performance accomplishments or experience, (2) vicarious experience or modeling, (3) social persuasions, and (4) physiological and emotional states. Performance accomplishments are viewed as the most important contributor to self-efficacy and are the extent to which there has been previous success in performing the task. Vicarious experience includes ones perception in regards to peers academic successes. Social persuasion is the extent to which others, such as teachers and parents, have been encouraging in the performance of the task. Lastly, physiological arousal produced from the learning situation can influence perceptions regarding one's ability to actually perform a task.

Research has indicated that students' introduction and advancement within public education tends to negatively affect student's self-efficacy beliefs. Reasons for this phenomena point to traditional school teaching and learning environments and stresses incorporating peer competition, ability grouping, norm-referenced teaching and grading, and delayed academic recognition or feedback due to large student to teacher ratio (Schunk, 2002; Bandura, 1997). Furthermore, "lock-step sequences of instruction frustrate some students who fail to grasp skills and increasingly fall behind their peers" (Schunk, 2002). Using CAI may be one way to provide the added and individualized instruction needed by those students who fall behind academically and in the process develop low self-efficacy beliefs.

This study was designed to explore not only multiplication mastery but also to what extent TA game play, designed to provide an engaging and motivational, self-evaluative, self-paced environment, affects students' multiplication self-efficacy.

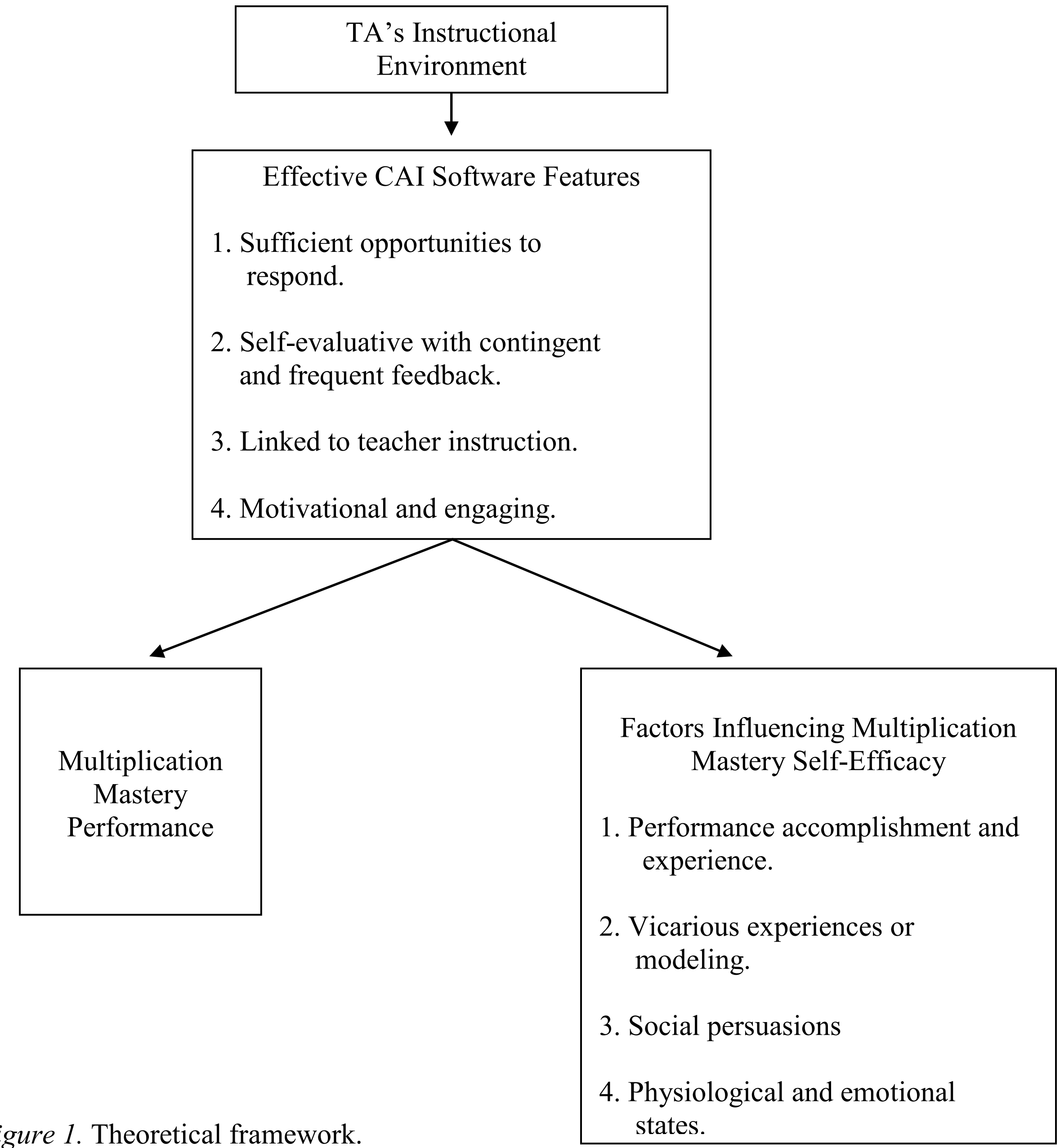

Figure 1. Theoretical framework.

In light of Bandura's (1997) self-efficacy research, CAI would seem to affect students' multiplication self-efficacy if it was found to impact some or all of the four constructs described by Bandura (1997) as having the greatest influence on academic self-efficacy. Figure 1 above provides a mapping of my theoretical framework and the relationships existing between constructs.

As illustrated in Figure 1, educational software programs like TA that includes effective software features may potentially affect students' multiplication self-efficacy as CAI can provide a more private self-evaluative learning environment. Past research has shown that this type of learning environment can actually reduce some student's levels of anxiety and provide more positive emotional states than that found among students in some whole class teacher-led-instructional environments (Wittman et al., 1998). Also, as effective CAI software features potentially motivate and improve students' multiplication mastery, any positive academic experiences, both personally and vicariously, might also positively affect students' self-efficacy (Pajares, F., & Kranzler, J, 1995). CAI may also influence self-efficacy beliefs when they include Internet-based features, like those found in TA, which provide teachers continual assessment of students' academic progression. This assessment provides teachers knowledge of students' success and struggles so they may provide students with appropriate social support. Bandura (1997) suggested social support has a significant influence on students' self-efficacy beliefs. Any improvement in students' self-efficacy beliefs produced through an effective CAI learning environment may then in return also improve student's academic performance (Bandura, 1997).

CHAPTER III: LITERATURE REVIEW

In order to sufficiently cover past research findings relative to all of the critical aspects of my study, this literature review incorporated a broad range of previous CAI research. First, educational CAI studies not specific to multiplication or even mathematics but that statistically compared changes in both student academic performance and attitudinal outcomes, are reviewed. Second, because TA is a mathematical related video game, existing studies investigating learning mathematical skills through video game play are included. Third, research specifically exploring multiplication CAI software is presented. Finally, pilot study results are discussed followed by the primary research questions.

Educational CAI Research

Kulik (2003) conducted a meta-analytic of 27 studies investigating CAI's possible educational benefits across various subject matters. Most of these studies only explored academic outcomes. In those studies that did explore both students' attitudes and academic performance Kulik stated that a positive relationship resulted in both improved academic abilities and students' attitudes. Attitudes measured in these studies looked at changes in students' enjoyment toward learning the subject content and instructional methods. In five out of these six attitude and performance studies, CAI test subjects outscored non-CAI participants by margins large enough to be considered both statistically and educationally significant. In a review of Kulik's meta-analytic study, Stokes (2008) stated that the median achievement effect size for these studies was .59 suggesting that CAI students would score in the 72nd percentile on their tests. Results from students receiving traditional instruction alone without any additional CAI indicated only 50th percentile performance. Measures used to determine CAI students' attitudes were also positive with an effect size of 1.1. Table 1 summarizes the achievement and attitude results from these five studies in Kulik's (2003) meta-analysis. A similar table excluding grades can be found in Stokes (2008).

Table 1
Computer-guided Instruction Meta-analysis Results

				Effect Size	
Study	Subject	*n*	Grade	*Achievements*	*Attitudes*
Bain, Houghton, Sah, & Caroll (1992)	Social Problem Solving	40	Middle School	.76*	1.10*
Gardner, Simmons, & Simpson (1993)	Weather	93	Elementary	1.06*	.43
Jegede, Okebukola, & Ajewole (1991)	Biology	64	Secondary	-.01	3.71*
Lazzarowits & Huppert (1993)	Biology	181	Secondary	.42	NA
Yalcinaip, Geben, & Ozkan (1995)	Chemistry	101	Secondary	.42	.33

Note. * Indicates statistically significant values.

While these studies primarily involved secondary age students and were not specific to multiplication mastery and self-efficacy or even mathematics, they are related in that they provided data suggesting that at least some educational CAI programs may improve both educational performance and attitudes. Furthermore, these studies also suggested a positive relationship existing between academic performance and various attitudes toward learning. Therefore, they offered motivation for further studies looking at the impact that CAI environments, specifically those created through video game play, like TA, might also have on elementary age students' level of multiplication mastery and self-efficacy.

Mathematical CAI Video Game Research

Several studies have evaluated the effectiveness of mathematical video game software. Kebritchi et al. (2010) explored the effectiveness of pre-algebra and algebra games *Evolver*™ and *Dimenxian*™ in improving achievement scores and academic motivation for a sample of 193 U.S. secondary age students and 10 teachers. They also studied whether the impact varied according to the students' prior knowledge, computer experience, and language background. The authors interviewed 15 students and three teachers and administered pre- and post district-wide benchmark exams, a DimM game math performance test generated by the game publisher, and a course motivation survey to students randomly assigned to experimental/control groups. Results revealed a significant achievement difference on exam scores (experimental students improved, on average, 8.07 in contrast to 3.74 for the control). Because the game publisher created the performance tests, however, it is possible that these results may be biased.

Personal student and teacher interviews found that game play seemed to increase the attention span of students. It accommodate various learning styles and motivated students to pay closer attention to learning so they could master and achieve the necessary math skills in order to accomplish the game objectives. Some students also reported that it gave them an alternative reason to achieve, as opposed to just getting a good grade. Thirteen of fifteen students interviewed said they preferred the games to other school activities: homework, class assignments, worksheets, etc. It entertained them in a fun, challenging, adventurous way in which they were able to explore while solving problems and learning mathematics.

Results from Kebritchi et al. (2010) study supported using mathematical video games to improve secondary age students' algebraic performance and some mathematical attitudes. Their study's results, however, may or may not hold true with other video software programs used for younger elementary age students' more basic mathematical skills and self-efficacy beliefs. Their results do support the further study into video game play's effect on students' performance and attitudes in other mathematical areas and with other age groups.

Moss (2004) conducted a study exploring changes in 64 male and 80 female third- and fourth-grade students' performance and attitudes after playing *Logical Journey of the Zoombies.* This software program employed video game play to teach mathematical reasoning, including deductive reasoning and hypothesis testing. The study showed that amount of game play in some student responses on the pre- and post-math attitude survey test was a statistically significant factor in explaining (7.9% in one case and 13.6% in the second) the variance in the changes to student responses. Those in the experimental group responded more positively in the post-test compared to comparison subjects.

Unlike Kebritichi et al. (2010) this study found no significant differences in mathematical performance in pre- to post-test comparisons between the experimental group and comparison group which used teacher-led paper and pencil practice. The author stated that this might be attributed to the fact that the achievement pre-test and post-test unknowingly had many questions that were academically four years advanced. Subjects from all groups were therefore unlikely to show much improvement in groups. Therefore, while this study was conducted with younger elementary age subjects, flawed pre- and post-tests showed no academic improvement and the researcher stated that further research was warranted.

The Cognition and Technology Group at Vanderbilt (CTGV) (1992) conducted a yearlong study including 730 students from 37 fifth- and sixth-grade classes. Two experimental and control classes, matched according to math ability and curriculum, were chosen from each site. The study investigated the effects of a computer video game series, *The Adventures of*

Jasper Woodbury. This study was designed to motivate students and help them improve their mathematical reasoning, problem posing and problem solving skills by requiring students "to formulate and solve a set of interconnected sub problems" (p. 295) before advancing in the game and discovering how the video character solved the same challenge.

Assessment designs included four test instruments: the Basic Math Concepts Test, Word Problem Test, Planning Test and Math Attitudes Questionnaire. Pre- and post-test comparisons found a significant academic improvement in experimental groups over control groups. Within the experimental group academic performance and attitudes toward learning had a positive correlation. Experimental students response to the Math Attitude Questionnaire revealed a significant decrease in anxiety toward learning.

Qualitative data found Jasper video game play to make mathematics more enjoyable and understandable then teacher-led methods. One student commented to others regarding what he liked about Jasper was not only that it was fun, but also that you "learn so much" (p. 308) from it. Jasper study researchers also observed positive vicarious modeling as students collaborated in efforts to advance through the video game. They also acknowledged their peer's mathematical accomplishments to be related to and influenced by Jasper video game play.

Although Jasper series experimental groups significantly outperformed control group students in mathematical reasoning and problem solving similar to Kebritchi et al. (2010), all four test instruments were created by the software developer and it is possible that statistical results from this study might also be biased. Furthermore this study was conducted 20 years ago with what would be now a very outdated program likely no longer appealing to and producing the same results with today's students.

In summary, past mathematical video game CAI research focused on more complex mathematical knowledge in secondary and older elementary-age students. It did not look at its effects on younger elementary-age students' more basic mathematics skills like multiplication mastery. Although studies reported that mathematical computer video games improve students' attitudes toward learning and reduce levels of anxiety, results regarding learning performance outcomes were mixed. This may be partially due to the use of flawed and biased pre- and post-tests. Therefore further research also including younger elementary age students is warranted.

Multiplication CAI Research

This section reviews research involving past CAI software programs designed specifically to improve multiplication mastery. Reviews included CAI studies, which may or may not have explored or discussed changes in areas possibly related to student's multiplication self-efficacy beliefs; however, they were still relevant in that they addressed effects the software seemed to have on subjects' multiplication mastery.

Wittman et al. (1998) conducted a study involving 63 fourth-grade students. Their research investigated the relationship between mathematics anxiety and multiplication fact mastery using *The Math Builder Program,* a CAI self-evaluating program designed to improve basic mathematic recall using drill and practice. Students were given a pre-math anxiety test using the MARS-E (Suinn, 1988) 26-item rating scale. Twenty-four students chosen from the upper thirds of the mathematics anxiety distribution formed two experimental groups with a control group of 12 students randomly selected from the remaining original student pool.

Wittman et al. (1998) reported that the CAI implemented was successful in helping improve students' multiplication fact automaticity. Interestingly, CAI "students in the high anxiety group averaged the greatest improvement in performance and were indistinguishable from the low anxiety group" (p. 478) by the end of the study students, specifically females, in the high anxiety group showed significant reduction in post-test math anxiety scores; however, no significant change in mean anxiety scores were found in students in either of the low anxiety or control group. According to Wittman et al., CAI based instruction is "impartial, reinforcing, appeals to student interest, and also offers a sense of privacy for students who are anxious or self-conscious about their performance" (p. 480), and was thus instrumental in the reduction of anxiety among some study subjects.

This study did support the fact that CAI can be a useful tool in helping some students reduce high levels of anxiety and improve multiplication mastery. It did not, however, consider the possible important overall affects that learning in a CAI environment might have on other factors influencing students' multiplication self-efficacy.

Bouck et al. (2009) investigated benefits of CAI in special education students' ability to improve multiplication automaticity. Their study explored three twelve-year-old special education students' use of the FLY™ Pen, a pentop computer that provides auditory output as it prompts students to complete a variety of tasks in improving their multiplication automaticity. Data collection and assessment consisted of three phrases: baseline, intervention and maintenance. Prior to subject's use of the pentop computer, assessment of each student's multiplication mastery was determined. After intervention, individual subject pre- and post-test comparisons indicated a significant increase in mean percentage of correct math facts completed. Bouck et al. stated that this might be attributed to the fact that the FLY™ Pen provided immediate individualized feedback of correctness and understanding of multiplication learning.

Bouck et al. (2009) did find CAI to improve multiplication mastery. This study, however, had no comparison group and its extremely small study pool of only three special education students affected the reliability of this study's statistical finding.

Irish (2002) conducted a study that investigated the effectiveness of CAI in obtaining multiplication mastery in six special education students preforming at least two or more standard deviations below average on a standardized mathematics achievement tests. This eighteen-week study using the computer software program *Memory Math* employed a single-subject, multiple-baseline design. Data was collected in four phases: baseline, intervention, maintenance, and follow up. Results after the interventional phase showed that all six students more accurately retrieved a greater number of multiplication facts than on their initial paper/pencil pre-tests. Furthermore, four of the six students achieved post-test scores of 85% or higher through the maintenance phase. This study does show promise for CAI as a useful tool in improving special education students' multiplication mastery. Similar to Bouck (2009), however, it was conducted with an extremely small academically similar population of students with no comparison group.

Williams (2000) employed 26 public school students from one class to be participants in a comparison study between effectiveness of CAI and teacher-led paper and pencil instruction (PPI) methods in improving student multiplication automaticity. Subjects in both the CAI and PPI groups received eight 30-minute multiplication practice sessions over a two-week period. The test group (CAI) used the computer software package, *Multiplication Puzzles*. The control group (PPI) used "Minute Madness" worksheets. A statistical analysis of pre- and post-tests data showed students in the CAI group to have a significant increase ($p < .05$) in multiplication mastery over students in the PPI group. CAI group subjects' post-tests "showed a significant increase in the number of problems correctly completed" (p. 1) while PPI groups' did not.

Although not specifically assessed in the study, Williams (2000) did note that students in the CAI group seemed to enjoy multiplication practice sessions. PPI participants on the other hand appeared to "became disinterested in trying to improve their math skills" (p. 42) and this may have contributed to CAI students' better performance. Therefore, studies looking more specifically at CAI's effect on students' attitudes should be considered.

Not all multiplication CAI research has shown it to be a more effective than other methods in improving student's multiplication mastery. Wong and Evans (2007) conducted a study that included 64 fifth grade students. Two experimental and two comparison groups practiced multiplication facts over a four-week period in 11 15-minute sessions. Comparison groups used teacher-led paper and pencil instructional (PPI) worksheets. The two experimental groups used a multiplication computer software package entitled *Back to Basics Maths Multiplication.* Changes in PPI CAI subjects' mastery levels were determined through timed multiplication pre- and post-tests.

Sample t-test results indicated that the pre-test mean multiplication score between CAI (n= 37, M = 22.27, SD = 10.685) and PPI groups (n = 27, M = 22.63, SD = 15.307) did not differ significantly; however, the regression model which used two predictors, pre-test and group, to explain post-test variance suggested that teacher-led PPI was a more effective method of improving multiplication mastery. Wong and Evans (2007) used a software package, however, chosen specifically because of its non game-like features. The program they used was self-evaluative and linked to teacher instruction, but it did not have the other same engaging and motivational features that might be found in a multiplication video game like TA.

Wilson et al. (1996) conducted a single–subject, alternating treatments design study involving four third- and fourth-grade elementary students whose test scores provided evidence of multiplication math fact deficiencies. The study compared effectiveness of two modes of instruction CAI, using the computer software program *Math Blaster,* and teacher-led instruction (TLI). Student multiplication mastery progress was monitored through a series of pre-tests, probes, and post-tests. While both methods resulted in improved multiplication mastery, analysis of data showed TLI to be more successful in helping students achieve multiplication automaticity. According to the authors "the magnitude of difference varies across students, ranging from 4% to 34% higher success rates in the TLI condition; however, the authors indicated that the small student-to-teacher ratio in the TLI groups may have been a contributing factor and that further research in more traditional classrooms or "authentic instructional situations," is warranted (p. 390).

In summary past multiplication CAI research studies focused on using quantitative measures testing primarily for performance outcomes and did not consider CAI's possible impact on all four of the factors which Bandura (1997) suggested most influences self-efficacy beliefs. Also, perhaps partially due to rapid changes in technology, differences in software program features, small study pools and studies that lacked comparison group's mathematical CAI research has reported mixed results in regards to performance outcomes. My study was designed to address limitations found in other studies and assessed both quantitatively and qualitatively CAI's effect on younger student's basic multiplication mastery and self-efficacy in a typical public school setting when compared to more traditional TLI methods. Also, contrary to some past CAI research, TA, the software package used in this study, incorporates the four features (outlined in my theoretical framework), which other researchers have noted as necessary in creating effective CAI software programs. Timez Attack is also an easily accessible modern Internet based 3D video game having the latest graphic capabilities. As technology advances, there is a continual need for better theory-driven research assessing the most modern CAI environments impact on student's learning (Wong and Evan, 2007).

Pilot Study

Prior to this study, a TA product evaluation was completed. Part of this evaluation acted as a pilot study for this current study. The pilot study happened late in the school year. The study focused on the 12s math facts because this was the only fact (0-12) the subjects had not yet been formally taught. A total of 22 second and third-grade students were divided into an experimental and comparison group. Pre- and post-test instruments were used to measure changes in ability and self-efficacy of participants after one 30-minute session with either TA game play or teacher-led instruction (TLI).

A pre- and post 12s two-minute timed multiplication test showed increased multiplication mastery in both groups. Pre- to post-test comparisons showed that TA students attempted an average of 11.5 more problems while answering an average of 12.9 more problems correctly on the post-test. The students also made an average of 1.5 fewer errors and reduced their error rate from 21.7% to 6.6% of attempts following their Timez Attack experience. Results from the TLI group showed that students attempted an average of 10.5 more problems while answering an average of 15.1 more problems correctly. The students made an average of 1.5 fewer errors and reduced their error rate from 35.2% to 4.4% of attempts following the classroom instruction received from their teacher. Comparisons between groups provided no significant difference in effectiveness of TLI and TA game play, with comparison group post-test scores being only slightly higher.

Due to a compressed time frame, only a short five question Math Attitudes pre- and post-Survey (MAS) was administered to students. Pre- and post-survey comparisons found TA subjects to have less anxiety and greater enjoyment toward learning multiplication after TA game play, and TA subjects over the comparison group felt greater self-efficacy in their ability to learn new multiplication facts.

Qualitative data collected during TA game play found students both enjoyed and were engaged in TA's learning environment. Comments like "This game makes me feel better at math," "I like how it's a fun game and you can learn math in a fun game," were often heard.

In summary, both quantitative and qualitative pilot study data seemed to suggest that TA game play not only improved multiplication mastery and self-efficacy, but students found satisfaction and enjoyment in multiplication math fact learning through the motivational, multi-sensory learning environment TA game play provided; however, no significant difference in increased multiplication mastery between TLI and TA groups was observed. This may be due to the fact that the comparison group received current research kinesthetic-based math instruction from their teacher. Therefore, the comparison group included instruction that may not represent the typical teacher-led math instruction; however, the fact that the TLI group did not significantly outperform intervention participants actually could be considered as strengthening TA's multiplication mastery effectiveness. Additional research is needed to better understand the value of TA game play.

Limitations to the pilot study, which were addressed in my current study, included a compressed time frame with only one intervention experience. One experience seemed inadequate in gathering sufficient and reliable data, and also did not allow for any consideration to retention of facts. The pilot study, unlike the final study, included a very small population of students all from the same class. While this does not necessarily invalidate findings, it does limit inferences that may be drawn to a larger population of students. Also, the MAS included only 5 valid questions and did not sufficiently address students' self-efficacy beliefs or possible factors impacting self-efficacy.

Research Questions

Unlike some traditional methods of basic multiplication math fact instruction and practice, some CAI software programs have the capability of providing students a fun, engaging, self-passed, self-evaluative and potentially less stressful learning environment. My study provides a theoretical evaluation of the impact of TA's modern video game play environment on students' multiplication performance and self-efficacy. More specifically, the following principal research questions will be answered:

1. To what extent does TA game play affect multiplication mastery among third-grade and fourth-grade elementary students?
2. To what extent does TA game play affect multiplication mastery when compared to teacher-led instruction?
3. To what extent does TA game play affect multiplication self-efficacy among third-grade and fourth-grade elementary age students?
4. To what extent does TA game play affect multiplication self-efficacy when compared to teacher-led instruction?

CHAPTER IV: METHODOLOGY

Research Design

This study was designed to determine what effect learning multiplication facts through TA's self-evaluative, self-paced, and engaging instructional environment has on students' basic multiplication math facts mastery and self-efficacy. Analysis compared the impact of TA game play verses more traditional teacher-led instruction (TLI) methods on students' multiplication mastery and self-efficacy.

Subjects in this study came from four third- and four fourth-grade elementary school classes. Two third- and two fourth-grade classes of students were assigned to a comparison or experimental group. Classes consisted of students at varying academic levels.

This study employed a mixed methods approach. This method was chosen because quantitative methods allow for data collection with larger numbers of participants in a single study, providing statistical reliability and comparability of a greater amount of data. Qualitative approaches can provide a more contextualized in-depth participant perspective. This may provide thicker data results than what might occur from a quantitative-only research study. Other non-CAI studies exploring academic performance and self-efficacy beliefs have also used mixed methodology approaches (Klassen & Lynch, 2007).

An experimental pre-test post-test research design was used as illustrated in Figure 2 below where E = experimental groups, C = comparison groups, P_1 = pre-test/survey, P_2 = post-test/survey, and X = intervention (i.e. TA game play). Quantitative comparisons were primarily done within similar grade levels, thus study groups were often separated into just third- or just fourth-grade students making two experimental and two comparison groups. Field notes, including recorded observations and informal interview responses, were also used to collect data during experimental group and comparison group sessions.

E	P_1	X	P_2
C	P_1		P_2

*Figure 2***.** Research design.

Subjects and Study Sessions

Subjects for the study consisted of students from four third- and four fourth-grade classes attending a local public charter school. Although subjects came from the same school, many of the students were bused or driven in from several surrounding cities. All students from each of the eight study classes were invited to participate in the study. Subjects ranged from high achieving to low achieving students and came from different ethnic backgrounds; however, the overwhelming majority of students were Caucasian.

Modes of multiplication practice included TLI methods in the two third- and two fourth-grade comparison groups and TA game play in the two third- and two fourth-grade experimental groups. Comparison group teachers were asked to provide students with the same amount of practice time and sessions as the experimental groups using TA. Multiplication mastery activities varied among comparison groups depending on the teacher and age of students.

Description of Timez Attack (TA)

Timez Attack was designed to motivate and engage students in the learning of multiplication facts through video game tactics intended to appeal to elementary age students. Students can only "win the game" by mastering their basic multiplication facts. The game is set in a three-dimensional environment wherein a single player controls the movements of either an alien-like or princess-like character in the third-person through various fantasy worlds. The objective of the game is to guide this character through various regions or levels using the multiplication understanding and skills the game teaches them. To reach higher levels, students must overcome frequent encounters with opposing computer characters that challenge them with multiplication problems, or tests. Encounters typically begin with the player arriving at an impassable obstacle, such as a locked door. The game then presents a multiplication problem with a multiplicand and multiplier and provides the player with a number of creatures (e.g. snails, robot spiders) equal to the multiplier, each with the value of the multiplicand. The player must gather all of these creatures and throw them at the obstacle. This action visually adds up each creature as a copy of the multiplicand until the sum equals the correct answer (see Figure 3). This part of the game teaches students that they can arrive at a correct answer to a multiplication fact by using count by (or skip counting) strategies. Students are familiar with this method as it has previously been a part of their teacher-led instruction. Consequently, with students in my study TA does seem to be linked to TLI.

After throwing the creatures at the obstacle, the player is then asked to type in the correct answer, which was just revealed by throwing the creatures. If the student types in the correct answer, the obstacle or door opens. An enemy (e.g. a troll, a dragon) then emerges to challenge the student. The student must rapidly answer multiplication problems that appear on the enemy's body by typing the correct answer within a short period of time. Each time the student provides a correct answer the enemy's "health bar" depletes by degrees. Often when the student provides an incorrect answer their character is punished by an attack, which depletes part of his or her health bar, and the enemy's health bar recovers some degree of health. The student defeats the enemy after delivering a certain number of correct answers. The enemy then disappears, allowing the player to pass to the next area or obtain a key to open a locked door.

Figure 3. Screen shot from Timez Attack video game of player gathering snails.

Each world is composed of twelve levels, which culminate in a final challenge wherein the player must answer all the variations of multiplication problems encountered previously in that particular world. Unlike regular computer character encounters, the "final boss," a video game character that tests students on multiplication facts, does not respond to incorrect answers; however, the student must achieve 100% accuracy to defeat "the boss" (see Figure 4). Beyond encounters with enemies, the student must evade environmental hazards such as falls from cliffs or bridges, falling rocks, etc. Failure to do so may result in depletion of the student character's health, or in resetting the character to an earlier position in that level in which the student must then re-advance through the level, thereby allowing them more math fact mastery practice.

Figure 4. Timez Attack screen shot of encounter with “final boss.”

As described above, in trying to advance through each level and beat “the final boss” the students are able to self-evaluate their progress as they are provided with instant feedback as to the correctness of their answers. In order to help the student learn facts, they are given multiple opportunities to respond to each fact as they try to advance through each level. Students are also sometimes asked to respond to multiplication facts from previous levels to test retention of facts. Therefore the subsequent, contingent, and frequent feedback seemed to be features included in TA game play. Furthermore, in order to assess changes in students’ level of proficiency, TA provides students with a basic 2-12 multiplication fact pre-test before they begin the game, and then the same test after having successfully advanced through all levels. Students may skip levels of play or learning of facts in a level if pre-test scores show mastery of those facts.

Research Instruments and Methods

Research instruments and methods included a 100-item multiplication two-minute 2-10s fact times test, Multiplication Attitude Survey (MAS) with both quantitative and qualitative sections, student observations and informal interviews.

Quantitative Research Measures

An existing 2-10s 100-item multiplication two-minute timed pre- and post-tests were administered to all participants to help determine effects of TA on multiplication mastery (see Appendix A). The exact same version was used for both the pre-test and the post-test.

The MAS (see Appendix B) was administered to assess TA game play's possible impact on students' multiplication self-efficacy beliefs. The four factors Bandura (1997) suggested as having the greatest impact on self-efficacy beliefs (discussed in my theoretical framework) guided the designing of the pre- and post-MAS. The survey contained 22 Likert-type questions and 5 open-ended questions. Likert-type response options on the MAS involved a five-point scale and included "FALSE, false, ?, true, TRUE" - with the two extreme options being in bolder type to make it easier for students to interpret the rating choices. Instructions on how to interpret the scale were verbally explained to students in advance by saying something similar to, "Circle the big 'FALSE' if you think what the statement says is ALL FALSE," "If you think what the statement says is mostly false, circle the little 'false'," and so on. Nichols, Cobb, Wood,Yackel, & Patashnick (1990) demonstrated the use of similar methods of administration on second-grade students using the same response options as mentioned above. The MAS was composed of seven different scales. To determine the reliability of these scales Cronbach's alpha coefficients were calculated by examining the responses given by the students participating in my study.

The first five questions on the MAS survey are related to multiplication self-efficacy and were adapted from the Patterns of Adaptive Learning Scales (PALS) (PALS, 2000). The MAS five-question efficacy scale had an alpha coefficient of .85. Wording for the MAS was changed to reflect multiplication self-efficacy instead of overall academic self-efficacy. Table 2 shows PALS original questions and changes that were made to the MAS in this study.

Table 2
Adapted Self-Efficacy Questions

PALS Self- efficacy Questions	Adapted MAS Self-efficacy Questions
I'm certain I can master the skills taught in class this year.	I'm sure I can master the multiplication facts taught in class this year.
I'm certain I can figure out how to do the most difficult class work.	I am sure I can figure out even the hardest math problems that involve using multiplication math facts.
Even if the work is hard, I can learn it.	Even if new multiplication math facts I am taught seem harder than others, I can learn them.
I can do even the hardest work in class if I try.	I can master even the hardest multiplication math facts if I try.
I can do almost all the work in class if I don't give up.	I can master all of the multiplication facts if I don't give up.

Physiological and emotional states relating to enjoyment, anxiety, and performance experience questions were adapted from some of the questions contained in the Attitudes Toward Mathematics Inventory (ATMI) (Tapia, 2004). This survey was designed to measure students' attitudes toward mathematics. It is composed of four separate scales or factors. In order to make the instrument suitable in length for elementary age students, not all questions from the ATMI factors were used in developing the MAS. The alpha coefficient for they anxiety scale used in my study was .71 with enjoyment scale ($\alpha = .79$). Since there were only two performance experience questions no alpha coefficient was tested and analysis looked at these two questions only individually.

Table 3
Physiological and Emotional States, and Performance Accomplishments Questions

ATMI Scale Factor 1 Questions	Adapted MAS Anxiety and Performance Experience Questions
Mathematics does not make me scared at all.	Learning multiplication math facts does not scare me at all.
Studying math makes me feel nervous.	Learning multiplication math facts makes me nervous.
My mind goes blank and I am unable to think clearly when working with mathematics	My mind goes blank and I am unable to think clearly when solving problem involve using multiplication math facts.
It makes me nervous to even think about having to do a mathematics problem.	It makes me scared to even think about having to learn multiplication math facts.
I am able to solve mathematics problems without too much difficulty.	The multiplication activities I do have helped me master almost all the multiplication facts I have learned in school this year
I learn mathematics easily.	In the past I have had success mastering my multiplication facts.
ATMI Scale Factor 3 Questions	**Adapted MAS Enjoyment Questions**
Mathematics is dull and boring.	Learning multiplication math facts is dull and boring.
I like to solve new problems in mathematics	I like to work on learning new multiplication facts.
I really like mathematics	I like doing activities that help me master my multiplication facts.

Motivation/engagement questions on the MAS ($\alpha = .70$) were adapted from a survey used by Chouinard, Karsenti & Roy (2007). This survey was created to assess relationships between competence beliefs, utility value, goals, and motivation to learn in mathematics and included three questions. Motivation scale questions were changed only slightly to include the words "multiplication facts" instead of "math."

MAS social persuasion questions ($\alpha = .78$) were adapted from three questions from the Teacher's Attitude scale, a part of the shortened Fennema-Sherman Math Attitude Survey (FSMAS-SF) (Mulhern, 1998). Changes to FSMAS-SF questions are reflected in Table 4.

Table 4
Adapted Social Persuasion Questions

FSMAS-SF Teacher's Attitude Questions	Adapted MAS Social Persuasion Questions
My teachers have made me feel I have the ability to go on in Mathematics.	My teacher makes me feel that I can learn my multiplication facts.
My teachers have encourages me to study more math.	My teacher encourages me to practice the multiplication facts I do not yet know very well.
My teacher encourages me to take all the math I can.	My teacher encourages me to learn all of my multiplication facts.

One vicarious experience question was developed specific for this MAS survey. The MAS Likert-type questions by scale factor can be found in Table 5, with the actual MAS found in Appendix B.

Qualitative Research Methods

The gathering of qualitative data included classroom observations, subject's oral responses to short informal interview questions, and participant's written responses to open-ended questions from the pre- and post-MAS (see Table 6). Some open-ended questions in this study's MAS were taken from a previous survey (Whitin, 2007). Question adaptations included the changing of the word "math" to "multiplication math facts." Observation and informal interview protocol along with a field note-recording sheet can be found in Appendices D and E.

Table 5
Likert-type Questions Pre- and Post-MAS

Scale Factor	Statements
Self-efficacy	I am sure I can master the multiplication facts taught in class this year. I am sure I can figure out even the hardest math problems that involve using multiplication math facts. Even if new multiplication math facts I am taught seem harder than others, I can learn them. I can master even the hardest multiplication math facts if I try. I can master all of the multiplication facts if I don't give up.
Physiological and Emotional States	
Anxiety	Learning multiplication math facts does not scare me at all. Learning multiplication math facts makes me feel uneasy and nervous. My mind goes blank and I am unable to think clearly when solving problems that involve using multiplication math facts. It makes me scared to even think about having to learn multiplication math facts.
Enjoyment	Working on mastering multiplication math facts is dull and boring. I like to work on learning new multiplication facts. I like doing activities that help me master my multiplication facts.
Motivation/Engagement	I try hard at mastering new multiplication facts that I am taught. When I do activities to help me master my multiplication facts I work very hard I do as little work as possible when it comes to mastering my multiplication facts. I keep working on learning new math facts until I have them mastered.
Social Persuasion	My teacher makes me feel that I can learn all of my multiplication facts. My teacher encourages me to practice the multiplication facts I do not yet know very well. My teacher encourages me to learn all of my multiplication facts.
Performance Experience	The multiplication activities I do have helped me master almost all the multiplication facts I have been taught in school this year. In the past I have had success mastering my multiplication tables.
Vicarious Experience	Most students in my class are able to master the multiplication math facts they have been taught.

The gathering of qualitative data was used to help determine whether CAI's learning environment was effective in improving students multiplication self-efficacy (and therefore possibly performance) by positively impacting some or all of the four self-efficacy factors in the stated framework as well as to understand the kind of instructional environments in the teacher led classrooms. As discussed in more detail in the data analysis section of this chapter a constant comparative method was used in the coding of qualitative data. Field note observations, answers to informal interview questions, and short response answers on the MAS were all used to provide triangulation of data and better insure the reliability in coding and analysis of qualitative data.

Table 6
Short Response Scales and Statements Pre- and Post-MAS

Scale Factor	Question
Physiological and Emotional States	How I have been learning my multiplication facts at school makes me feel…. I enjoy learning my multiplication facts when…
Performance Experience	Learning my multiplication math facts is easy when… Learning my multiplication math facts is hard when…
Vicarious experience	When I see other kids do well at learning their multiplication facts it makes me feel…because

Piloting the MAS. In order to pilot the MAS survey, it was administered to nine third- and fourth-grade students. The instructions were read, as well as each question. The students did not seem to have any difficulty understanding or answering the Likert-type questions. One question that did not seem relative to the study was deleted. Also the wording on question 20 was changed to better address differences in CAI and TLI practice sessions. The question "I have been able to master almost all the multiplication facts I have learned in school this year without too much difficulty," was changed to "The multiplication activities I do have helped me master almost all the multiplication facts I have been taught in school this year." The MAS survey took students an average of 15 minutes to complete, which was felt as not being an unreasonable amount of time to ask teachers to take away from their normal classroom routine in administration of the survey.

Data Collection Procedures

TA intervention periods consisted of 12 20-minute game play sessions spread out over a four-week period. Comparison group participants received an equal amount of in-class multiplication learning and practice time through various teacher selected TLI methods. Teachers chose methods they had typically used for the grade they were currently teaching. Not all methods were the same. The teachers chose methods that they were comfortable with and had previously used. Third-grade teachers used similar methods, as did fourth-grade teachers.

Quantitative Data Collection

Quantitative data was collected through multiplication fact timed pre- and post-tests and Likert-type question responses from the pre and post-MAS. The pre- and post multiplication test and MAS was administered orally by myself a few days prior to intervention and one day following the twelve intervention sessions.

Qualitative Data Collection

Qualitative data was gathered through open-ended pre- and post-MAS written responses, field note observations, and responses to informal interviews. Field note observations occurred twice in each of the eight study group classes. Classroom TLI observations were conducted during the 2nd, 3rd, 7th, and 11th TLI study sessions in third grade. Classroom observations and informal interviews were conducted during the 2nd, 4th, 6th and 10th TLI study sessions for fourth grade. All the students in the classroom were participants during TLI sessions. The students' regular classroom teacher conducted all of these sessions.

Classroom TA observations and informal interviews were all conducted in the students' classroom, where eight students at a time would rotate, spending 20 minutes playing Timez Attack at the back of the room while other students were working in non-related academic areas. Two 20-minute sessions in each of the two third- and fourth-grade TA classes were observed; however, due to the fact that students rotated through the laptop computers, not all students that were at the computer at the same time were always on the same TA session; thus during the recording of TA field notes, students observed at the same time were often on different sessions. Therefore, although only four third- and four fourth-grade TA sessions were observed, students TA game play experiences were seen in their 3^{rd}, 4^{th}, 5^{th}, 6^{th}, 7^{th} and 8^{th} for third-grade and 2^{nd}, 4^{th}, 5^{th}, 8^{th}, 9^{th} and 10^{th} sessions for fourth-grade participants.

Observations focused primarily on 7-10 students in each study group who were working in close proximity. Because I was interested in determining how the TA instructional environment might influence students' multiplication self-efficacy as compared to TLI groups, field note observations looked specifically for any student evidence of Bandura's (1997) academic self-efficacy constructs described in the theoretical framework. As stated previously, these constructs include: (1) performance accomplishments or experience, (2) vicarious experience or modeling, (3) social persuasions and (4) physiological and emotional states.

In order to help prevent biased recording of comments and observations, I always noted the very next episode from the students that my observations were focused on. An episode included any student comment, response to question, or action, during the study group session. The initial episode included the very first student observation and was recorded as episode 1.

After the initial recording, the next observed student episode was recorded as episode 2 and so forth. Each episode was categorized under one of the four self-efficacy constructs. If an episode could not be logically categorized under one of the self-efficacy constructs, it was temporarily coded as “other.” Questioning of subjects occurred primarily during the last five minutes of the practice session and continued, as time permitted, after the conclusion of the session. The informal interview questions asked were noted and student responses were recorded and numbered in order along with observed episodes. My observation and interview protocols including informal interview questions and an episode-recording sheet can be found in Appendices C and D.

Data Analysis

Both quantitative and qualitative data were analyzed as outlined in the quantitative and qualitative data analysis sections below.

Quantitative Data Analysis

In scoring the multiplication pre- and post-tests, students' overall correctness was determined by considering any written answer to a problem as an "attempt," every correct answer as a "correct response," and every incorrect attempt as an "error.”

The scoring of Likert-type questions (FALSE, false, ?, true, TRUE) from the pre- and post-MAS ranged from numbers 1 to 5 with 1 coinciding with ”FALSE” and 5 coinciding with “TRUE,” as shown in Figure 3.

1 = FALSE
2 = false
3 = ?
4= TRUE
5 = true

Figure 5. Coding of Likert-type responses.

Analysis of quantitative data collected from the multiplication pre- and post-tests and MAS was done similar to methods used in other CAI multiplication research (Wong & Evans, 2007). Using Rv2.11.1 statistical software, the effectiveness of TA game play on students' multiplication mastery and self-efficacy was tested using a hierarchical linear model (HLM) with post-test scores as the outcome variable and pre-test and treatment variables as the explanatory variables. HLM models are appropriate for this analysis because they take into account the nested structure of the data. The experiences of two students in the same classroom are more alike than two students in different classrooms. Analyzing the data at the student level using Ordinary Least-Squares (OLS) regression would violate an important assumption of that regression technique, the assumption that each observation (in this case data on each student) is independent of other observations. With the nested structure where students are nested in classrooms this is not the case. For example, knowing scores of students in one classroom gives some information (or more appropriately *might* give you information) about the scores of unobserved students in that classroom. They are not independent. HLM models takes this nested structure into account and allows variables at different levels, the student level and the classroom level, to be analyzed in a single model.

For this study significance was accepted at $p < 0.05$. Significance levels at $p < .01$ and marginal significances accepted at $.1 > p > .05$ were also reported along with $p <. 05$. Comparisons between TLI and TA pre-tests were first performed to identify any initial significant differences followed by post-test comparisons. Pre- to post-test comparisons within study groups were also performed. Findings were reported in table, graph, and explanatory form.

Qualitative Data Analysis

Qualitative data was analyzed using a constant comparative method (Mewborn, 2005). During observations, recorded episodes and written responses to interview questions fitting into the observation protocol categories were coded accordingly. Student responses from the MAS open-ended questions that could be categorized as a negative, positive, or ambiguous, were coded accordingly. Other data not seeming to fit into one of the pre-determined categories were set aside for later comparison. These data were later reviewed and grouped, allowing for other categories or subcategories to emerge. An assistant helped increase reliability of results by double-checking the coding. Disagreements in coding between the research assistant and researcher were discussed until an agreement was met. After the coding of open-ended responses, Microsoft Excel graphs were used to compare frequency of codes used between and within experimental and comparison groups. Coded data from episode and informal interviews provided contextualized examples when trying to determine and report the impact that TA game play seemed to have on students' multiplication self-efficacy.

CHAPTER V: RESULTS

Results are divided into three areas. First, details of the implementation of Timez Attack (TA) and teacher-led instruction (TLI) sessions are reported along with a description of the kinds of instruction TLI students experienced. Second, quantitative statistical findings from the 2-10s 100-item multiplication tests and MAS Likert-type responses are given. Third, qualitative findings from classroom observations, informal interviews, and written responses to MAS open-ended questions are reported. All statistical analyses of quantitative data were completed using Rv2.11.1. statistical software.

Multiplication Study Group Sessions

Facets surrounding the implementation of both third- and fourth-grade TA study group sessions are reported first with third-grade TLI sessions reported second followed by fourth-grade TLI sessions.

Third- and Fourth-Grade TA Sessions

Participants receiving CAI through TA game play primarily rotated through eight laptop computers in their classroom. Students were timed for 20 minutes and at the end of the 20 minutes logged off the game and the next group of students played TA for 20 minutes. This continued for a period of four weeks with each student having approximately three sessions a week until all students had 12 total sessions. Each class went to a computer lab two to three times where all students were able to all play TA at the same time for their 20-minute session. One third-grade teacher did have two back-to-back 20-minute sessions in the computer lab, and one third-grade class only received 11 TA sessions.

Third-Grade TLI Sessions

Sessions were either one 20-minute or two 20-minute sessions back-to-back. Although the teachers were asked to keep the sessions to 20 minutes, both teachers admitted that all practice sessions were extended at least 10 minutes over. Sessions started with students learning new multiplication facts through direct instruction (where the teacher would explain or show multiplication patterns, procedures, and facts at the board as the whole class listened) or through practicing facts with songs, rhymes, or skip counting (i.e. counting by twos, threes etc.). Students were taught multiplication as repeated addition, and as a certain amount of "groups" of the same number. For example two times three is "two groups of three." Students were taught some multiplication "tricks" such as when multiplying by 10, add a zero to the other number, or to multiply a number by five add a zero to the number like you are multiplying by 10, then cut your answer in half. During the last half of the session students practiced their multiplication facts through various multiplication games with dice, timed multiplication math fact competitions, or multiplication bingo. During some sessions students also competed in rows using beans as a way to represent the correct solution to a basic multiplication fact. Except during direct instruction modes of learning, practice seemed to involve some measure of peer or individual competition.

Fourth-Grade TLI Sessions

Fourth-grade students had been previously taught multiplication facts through 12 as third-graders. Therefore, any direct instruction mostly involved reviewing facts. This was done through skip counting and exploring various patterns found within the 12s times tables. Students were reminded of various multiplication "tricks" previously taught to them, such as when multiplying by 10 just add a zero to the other number. All sessions concluded with paper and pencil practice of multiplication facts. Some sessions in one fourth-grade TLI class also included individual student study time of multiplication facts. In this class paper and pencil timed multiplication tests were used, corrected by the teacher, and handed back the next day. If a student passed a specific facts test, they could then go on to the next fact family. Students started with 2's and progressed through 12's. Students in the other fourth-grade class always reviewed multiplication facts together and then were given a paper and pencil quiz that only included the facts they were reviewing that day. If students finished the quiz before one minute they would yell out their time. They were then given the same quiz with the same facts and each student tried to beat their own time. In this class, students corrected their own tests during class.

Quantitative Findings

Multiplication pre- and post-tests and pre-and post-MAS Likert-type responses were used to help identify any significant differences in students' multiplication mastery and self-efficacy after intervention and between TA and TLI study groups. A marginal significant difference between variables was assumed if a test produced a p-value of less then .1 but greater that .05 ($.1 > p > .05$). A significant difference was accepted at p <. 05. Significance was reported at both the $p < .05$ and $p < .01$ levels. Only data from students who participated for the entire length of the study were included in the statistical analysis and reported in this section. Findings from the analysis of pre- and post-multiplication tests are reported first followed by pre- and post-MAS statistical findings.

Statistical Analysis of 2-10s Multiplication Pre and Post-Tests

Multiplication pre- and post-tests were given and statistically analyzed to access TA's effect on students multiplication mastery performance. These tests were also used to compare TA and TLI students' performance outcomes after intervention. Multiplication pre- and post-tests comparisons of number correct responses are reported first by findings within each third- and fourth-grade study group and then between TA and TLI experimental and comparison groups.

Comparison of pre- post- multiplication tests within each study group. Statistical analysis of the 2-10s multiplication pre- and post-tests number of correct responses revealed that for third-grade (n=78) TA and TLI groups and fourth-grade (n=72) both TA and TLI groups, mean post-test scores did significantly exceed pre-test scores. Third-grade TLI students had a significant improvement starting at 12.1 mean correct responses and scoring 25.23 correct responses on average by the end of the study period. This is significant at $p < .05$ value and produced a hierarchical linear model (HLM) difference at 11.45. Third-grade TA students' average scores increased from 13.62 to 26.28 correct with a HLM difference at 11.26, significant at $p < .05$. Fourth-grade TLI students' average scores increased from 26.9 to 35.7 correct with an HLM difference at 7.00, significant at $p < .05$. Fourth-grade TA students' average scores increased from 29.8 to 49.62 correct with a HLM difference at 18.05, significant at $p < .01$. Mean scores on pre-tests and post-tests can be found in Table 7.

Comparison of pre- and post-multiplication test scores between experimental and comparison groups. Before comparing TA to TLI post-test scores, comparisons of pre-tests between TA and TLI groups were performed to determine if there were any pre-existing significant differences. Due to fourth-grade students having greater prior knowledge of multiplication facts than third-graders and differences in TLI methods between grades, mean scores were compared separately by grades for all statistical analysis. The HLM revealed that between grade levels TA and TLI 2-10s multiplication two-minute timed pre-test number of mean correct responses did not differ significantly (see Table 7).

Similar to pre-tests, analysis of post-test scores revealed no significant difference among third-grade TA and TLI groups; however, fourth-grade TA participants significantly outperformed fourth-grade TLI students (see Table 7). Fourth-grade TA participants had the greatest increase in number of correct responses from pre- to post-test of any study group. The fact that third-grade TA students did not out perform third-grade TLI students was not surprising. Unlike most fourth-grade TA students who advanced through at least the 10s level, third-grade students were learning most facts for the first time and the length and amount of study sessions did not allow most third-grade TA students to make it passed their 6 times facts. Third-grade TLI students were, however, taught all their facts through at least the 10s level. Furthermore, third-grade teachers displayed exceptional teaching skills. They used very little direct instruction, but provided, like TA a fun engaging environment incorporating a variety of multisensory activities to improve both multiplication mastery and conceptual understanding.

Table 7
Analysis of 100 Item 2-10s Timed Test Number of Correct

Grade/Test	TLI Mean	TA Mean	HLM Model estimate of difference
3rd grade Pretest	12.10	13.62	1.16
3rd grade Posttest	25.33	26.28	1.40
4th grade Pretest	26.9	29.8	2.91
4th grade Posttest	35.7	49.62	13.96**

Significance codes: ~, p<.1; *, p<.05; **, p<.01

Summary of Findings from 2-10s Multiplication Pre- and Post-Tests

Both TA and TLI groups had significant gains in mean number of correct responses from pre- to post- tests. When comparing performance between groups fourth-grade TA had the greatest significant increase at $p < .01$ while the other groups' post-tests mean improvement was significant at the $p < .05$. Comparison between third-grade TA and TLI and fourth-grade TA and TLI students' pre-tests scores showed no significant differences. Fourth-grade TA students' mean post-test scores rose significantly higher over TLI fourth-grade multiplication post-test scores, however, there was no significant difference in post-test mean level of multiplication performance between third-grade TA and TLI groups. Figure 4 provides information similar to that found in Table 7 but offers a visual interpretation and summary of pre-test to post-test gains both within and between study groups. Visual inspection of this graph also highlights the similarity between third-grade post-test scores and fourth-grade pre-test scores.

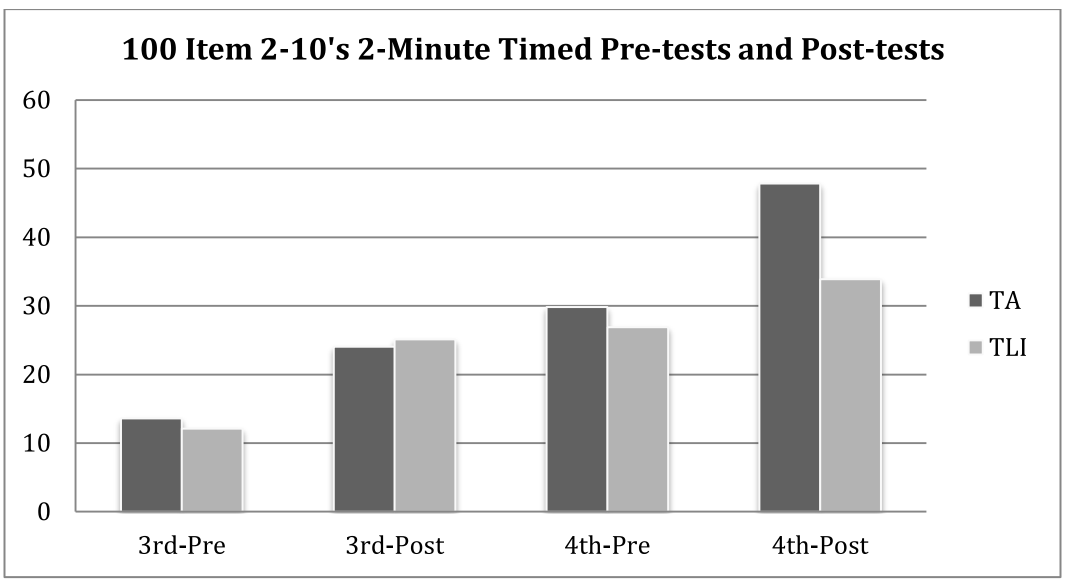

Figure 6. TA and TLI 2-10s multiplication pre-tests and post-tests average number of correct.

Statistical Analysis of Pre- and Post-MAS Likert-type Responses

Likert-type student responses to the pre- and post-MAS were statistically analyzed to access TA's effect on students' multiplication self-efficacy and factors possibly influencing students' self-efficacy. Pre- and post-MAS Likert-type questions were also used in comparing self-efficacy beliefs between TA and TLI students. Students' responses to pre- and post-MAS Likert-type questions were analyzed by scale factors and individual item response. Statistical analyses were performed both within and between third-grade TA and TLI and fourth-grade TA and TLI study groups. Results from the statistical analysis of scales are reported first followed by findings resulting from analysis of individual questions.

Comparison of pre- and post-MAS Likert-type scales response scores within each study group. Analysis of TA and TLI pre- and post-MAS Likert-type item mean responses grouped by scales found some significant differences within groups in two of the scales: self-efficacy and social persuasions.

Statistical analysis of MAS self-efficacy questions (Q1-Q5) pre- and post-survey mean responses to all five questions revealed that for TLI third-grade and TA and TLI fourth-grade, mean post-MAS scores did significantly exceed pre-MAS scores. Third-grade TLI students had a significant improvement with a pre-MAS self-efficacy mean score of 3.97 and post-MAS of 4.41. This is significant at a $p < .05$ value and produced a HLM difference at .44. Fourth-grade TLI students' self-efficacy mean scores increased from 3.92 to 4.36 with a HLM difference at .43, significant at $p < .05$. Fourth-grade TA students' average response scores increased from to 3.96 to 4.51 with an HLM difference at .56, significant at $p < .05$. Analysis of third-grade TA self-efficacy responses revealed no significant changes from pre- to post-surveys with a pre-survey score of 3.84 and post-survey of 3.92.

The only other statistically different scores found within study groups when analyzing the MAS by scales occurred between third-grade TLI pre- and post-MAS mean responses to social persuasion questions (Q17-Q19). TLI third-grade mean pre-survey score for this scale was 4.35 with a post-survey score increase of 4.59. This was marginally significant at .1 < p < .05 with a HLM of .24.

Comparison of pre- and post- MAS Likert-type scales response scores between experimental and comparison groups. Analysis of pre-MAS mean scores by scales between fourth-grade TA and TLI groups found no significant differences. This remained true in the post-survey analysis. Third-grade TLI and TA statistical comparisons of post-MAS scales found significant differences in one scale, the self-efficacy scale, where no initial significant differences existed. Analyses found TLI over TA students to have overall greater self-efficacy after intervention (see Table 8). Post-MAS analysis of mean responses to all social persuasion items also revealed significant differences between third-grade comparison and experimental groups. This was also true, however, in the pre-MAS analysis of scales (see Table 8).

Table 8

Pre- and Post-MAS Significant Differences by Scales Between Groups (post minus pre)

Grade/Test	Scale	TLI Mean	TA Mean	HLM Model estimate of difference
3rd grade Pre-test	Social Persuasion	4.35	3.81	-.54*
3rd grade Post-test	Social Persuasion	4.59	4.10	-.49*
3rd grade Post-test	Self-efficacy	4.41	3.92	-.48*

Significance codes: ~, p<.1; *, p<.05; **, p<.01

Comparison of pre- and post-MAS Liker-type individual item response scores within each study group. When comparing student pre- and post-MAS individual item responses within each group separately (see Table 9), third-grade TLI students' mean post-survey scores relating to some self-efficacy beliefs and feelings toward effort in learning showed marginal to significant positive increases from pre- to post-survey. Third-grade TA student responses' indicated that students' felt learning multiplication facts was significantly less dull and boring after intervention than prior to TA. Both TA and TLI students' responses were also marginally significantly higher in regards to some teacher influence in learning multiplication facts.

Table 9

Third-Grade Pre- and Post- Significant Differences on MAS Items (post minus pre)

Grade/Question	Group	Pre Mean	Post Mean	HLM Model estimate of difference
3rd grade, Q3 Even if new multiplication math facts I am taught seem harder than others, I can learn them.	TLI	4.15	4.61	.39~
3rd grade, Q11 When I do activities to help me master my multiplication facts I work very hard.	TLI	4.32	4.62	.29~
3rd grade, Q12 I do as little work as possible when it comes to mastering my multiplication facts.	TLI	2.10	1.47	-.61*
3rd grade, Q17 My teacher makes me feel that I can learn all of my multiplication facts.	TLI	4.55	4.79	.29~
3rd grade, Q18 My teacher encourages me to practice the multiplication facts I do not yet know very well.	TLI	4.02	4.50	.47~
3rd grade, Q14 Working on mastering multiplication facts is dull and boring.	TA	2.21	1.72	-.49*
3rd grade, Q19 My teacher encourages me to learn all my multiplication facts.	TA	3.84	4.30	.43~

Significance codes: ~, p<.1; *, p<.05; **, p<.01

TLI fourth-grade students responses on individual items showed marginal to significant differences between pre- to post-survey responses in three out of the 22 MAS Likert-type questions. Two of these related to increased self-efficacy beliefs (see Table 10). TLI student's level of nervousness showed a marginal significant decrease from mean pre- to post-survey response.

Table 10
TLI Fourth-Grade Pre- and Post- Significant Differences on MAS Items (post minus pre)

Grade/Question	Group	Pre Mean	Post Mean	HLM Model estimate of difference
4th grade, Q1 I am sure I can master the multiplication facts taught to me in school this year.	TLI	3.67	4.20	.52*
4th grade, Q2 I am sure I can figure out even the hardest math problems that involve using multiplication math facts.	TLI	3.20	3.93	.73**
4th grade, Q7 Learning new multiplication facts makes me uneasy and nervous.	TLI	2.73	2.25	-.46~

Significance codes: ~, p<.1; *, p<.05; **, p<.01

Fourth-grade TA mean response scores showed marginally significant to significant improvement on nine MAS Likert-type questions after intervention (see Table 11). Three of these questions related specifically to increased multiplication self-efficacy beliefs and two questions related to reduced feelings of anxiety in learning facts. They also felt significantly more confident after intervention that the activities they were doing in school were helping them master their multiplication facts.

Table 11

TA Fourth-Grade Pre- and Post- Significant Differences on Survey Items (post minus pre)

Grade/Question	Group	Pre Mean	Post Mean	HLM Model estimate of difference
4th grade, Q1 I am sure I can master the multiplication facts taught to me in class this year.	TA	3.90	4.51	.54~
4th grade, Q3 Even if new multiplication math facts I am taught seem harder than others, I can learn them.	TA	4.17	4.55	.32~
4th grade, Q4 I can master even the hardest multiplication math facts if I try.	TA	3.86	4.54	.66*
4th grade, Q7 Learning multiplication math facts makes me feel uneasy and nervous.	TA	2.21	1.69	-.52*
4th grade, Q8 My mind goes blank and I am unable to think clearly when solving problems that involve using multiplication math facts.	TA	2.33	1.76	-.60*
4th grade, Q10 I try hard at mastering new multiplication facts that I am taught.	TA	4.29	4.60	.31*
4th grade, Q13 I keep working on learning new math facts until I have mastered them.	TA	4.14	4.33	.19~
4th grade, Q20 The multiplication activities I do have helped me master almost all the multiplication facts I have been taught in school this year.	TA	3.83	4.50	.68**
4th grade, Q22 Most students in my class are able to master the multiplication math facts they have been taught.	TA	3.59	4.07	.46~

Significance codes: ~, p<.1; *, p<.05; **, p<.01

Comparison of pre- and post-MAS Likert-type individual item response scores between experimental and comparison groups. When analyzing each of the 22 questions individually, no pre-MAS Likert-type individual items had any initial significant mean differences between fourth-grade TA and TLI groups.

Mean scores on post-survey responses to anxiety questions found TA fourth-grade students to be significantly less nervous when learning multiplication facts than TLI fourth-grade students (see Table 12).

Table 12
Analysis of MAS Comparison of TLI to TA, Significant Differences in Fourth-Grade Students

Grade/Question	Survey	TLI Mean	TA Mean	HLM Model estimate of difference
4th grade, Q7 Learning multiplication math facts makes me feel uneasy and nervous.	Post	2.25	1.69	-.56*

Significance codes: ~, p<.1; *, p<.05; **, p<.01

Fourth-grade TA and TLI students' mean responses to the post-MAS question used to assess students feelings, in regards to their performance experiences (question 20), revealed the only significant difference when comparing TLI pre- to post-survey gains with TA surveys (see Table 13).

Table 13
Analysis of MAS Significant Gains from Pre- to Post-MAS

Group	TLI Gain	TA Gain	HLM Model estimate of difference
4th grade, Q20 The multiplication activities I do have helped me master almost all the multiplication facts I have been taught in school this year.	.03	.68	.64*

Significance codes: ~, p<.1; *, p<.05; **, p<.01

Figure 7 illustrates the significant gains in fourth-grade TA over TLI students to question 20. Notice that while TLI responses stayed relatively the same fourth-grade TA mean response increased from pre- to post-survey.

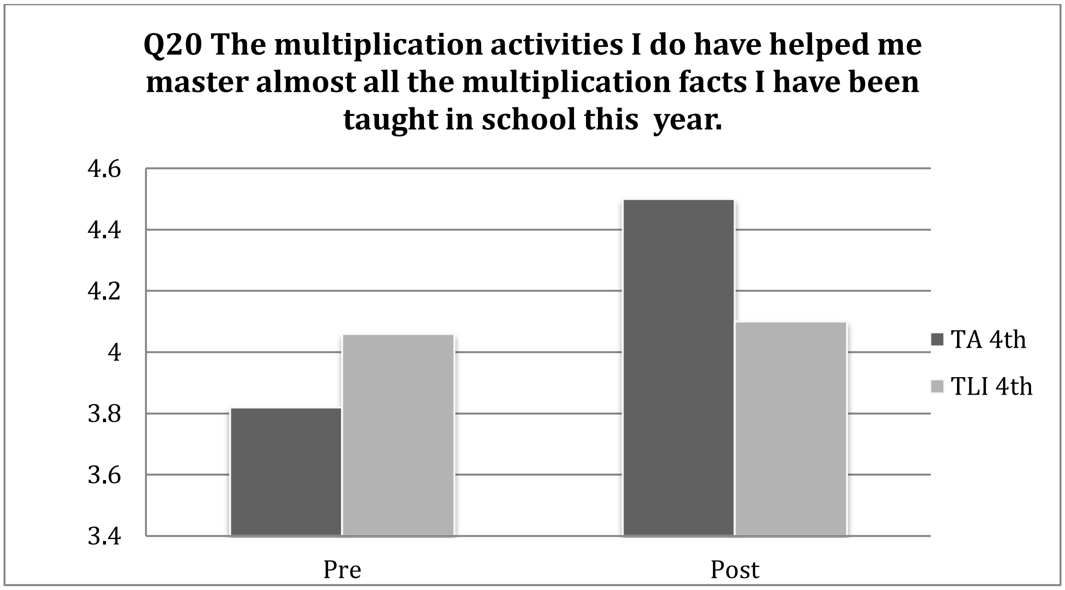

Figure 7. Fourth-grade comparison of pre- and post-MAS responses to question 20.

Unlike fourth-grade TA and TLI groups, third-grade experimental and comparison groups' pre-MAS individual item analysis found some significant response differences (see Table 14). Finding of any initial differences between third-grade groups was surprising as third-graders had not yet begun learning of multiplication facts with their current third-grade teacher. Differences in initial feelings in regards to enjoyment of multiplication activities and teacher encouragement to learn facts may have carried over from learning the 0s, 1s, 2s, 5s and 10s multiplication facts the end of students' second grade year, or third-grade students might have responded according to their feelings toward other mathematical learning experiences with their current teacher.

Table 14

Analysis of Pre-MAS Comparison of TLI to TA, Significant Differences in Third-Grade Students

Grade/Question	Survey	TLI Mean	TA Mean	HLM Model estimate of difference
3rd grade, Q16 I like doing activities that help me master my multiplication facts.	Pre	4.65	4.13	-.52*
3rd grade, Q17 My teacher makes me feel that I can learn all of my multiplication facts.	Pre	4.55	3.89	-.66*
3rd grade, Q19 My teacher encourages me to learn all of my multiplication facts.	Pre	4.47	3.84	-.63*

Significance codes: ~, p<.1; *, p<.05; **, p<.01

In response to post-survey questions, third-grade TLI students rated themselves as having significantly greater self-efficacy in both learning new facts and solving problems involving multiplication. TLI over TA third-graders also felt their teachers encouraged them to practice the facts they did not know. Post-survey mean response scores in regards to teachers making their students feel they can learn all their facts still, like in the pre-MAS analysis showed a significant difference in TLI over TA (see Table 15).

Summary of Findings from Pre- and Post-MAS Likert-type Responses

Analysis of MAS Likert-type responses did provide some evidence that TA game play had a positive impact on students' multiplication self-efficacy and factors impacting self-efficacy. Any significant changes from TA students' pre- to post-survey mean scores rose or declined favorably in post over pre-survey scores. Analysis of TA students MAS items by scale factors within groups found no significant differences between TA third-grade students' pre- and post-survey responses. Fourth-grade TA and TLI and third-grade TLI students, however, had significantly greater overall feelings of self-efficacy at the end of the 12 study sessions.

Table 15

Analysis of Post-MAS Comparison of TLI to TA, Significant Differences in Third-Grade Students

Grade/Question	Survey	TLI Mean	TA Mean	HLM Model estimate of difference
3rd grade, Q2 I am sure I can figure out even the hardest math problems that involve using multiplication math facts.	Post	3.87	3.23	-.64*
3rd grade, Q3 Even if new multiplication math facts I am taught seem harder than others, I can learn them.	Post	4.61	3.89	-.71*
3rd grade, Q4 I can master even the hardest multiplication math facts if I try.	Post	4.45	4.03	-.42~
3rd grade, Q12 I do as little work as possible when it comes to mastering my multiplication facts.	Post	1.47	2.28	.81~
3rd grade, Q17 My teacher makes me feel that I can learn all of my multiplication facts.	Post	4.79	4.21	-.61~
3rd grade, Q18 My teacher encourages me to practice the multiplication facts I do not yet know very well.	Post	4.5	3.82	-.72~

Significance codes: ~, p<.1; *, p<.05; **, p<.01

Analysis of MAS items individually found fourth-grade TA students responding significantly higher to three of the five multiplication self-efficacy questions and feeling significantly less nervousness in learning multiplication facts after intervention. MAS individual item analysis also revealed that TA third-graders felt learning multiplication facts was significantly less dull and boring than they reported in the pre-survey. Additionally, analysis of fourth-grade TA students' pre- and post-MAS individual item mean scores found significant improvement in nine out of the 22 Likert-type questions after intervention. This was the most number of improved individual item scores of any study group. Third-grade TLI students were next with improved scores on five items followed by TLI fourth-graders with three and TA third-graders with two. This coincides with TA fourth-graders having the greatest overall significant improvement in multiplication mastery scores of any group.

Comparison of TA and TLI post-survey items by scales between study groups found TLI third-grade students to have significantly higher overall self-efficacy beliefs then third-grade TA students. TLI over TA third-grade students also had significantly higher post-test scores to some individual self-efficacy, effort, and social persuasion questions. No significant differences were found in comparing TA and TLI fourth-grade students' pre- and post-MAS responses by scales. In analysis of MAS individual items, however, fourth-grade TA over TLI students reported that school activities helped them learn their multiplication facts. Fourth-grade TA over TLI students also reported significantly reduced levels of nervousness while learning multiplication facts after intervention.

Qualitative Findings

Qualitative methods including observations, informal interviews and student responses to MAS opened-ended questions were employed to add an additional, deeper and more contextualized understanding that cannot be found in quantitative measures. These methods were specifically designed to explore effects that TA and TLI's different learning environments had on students' multiplication self-efficacy beliefs. Qualitative data collection therefore was centered around the four factors, which according to Bandura (1997) have the greatest direct impact on students' academic self-efficacy. Qualitative findings were reported for third- and fourth-grade TLI and TA groups, based on these four factors and included: (1) physiological and emotional states, (2) vicarious experience, (3) social persuasions, and (4) performance accomplishments and experiences

Physiological and Emotional States for Third- and Fourth-Grade TLI Students

Recording of qualitative data discovered third- and fourth-grade TLI students to experience a variety of physiological and emotional states. Changes in students' moods seemed to occur as they fluctuated between various modes of teacher-led multiplication learning and practice. Evidence of student engagement, motivation, and enjoyment was most apparent as students participated in whole class activities, especially those more competitive in nature where students were observed excitedly shouting out answers. Peer competition activities however also reveled students exhibiting feelings of incompetency and nervousness. One student commented to another student that he was no good at multiplication when loosing to the other student in a multiplication activity. Students seemed most off-task and less motivated to succeed at mastering multiplication facts during times of direct instruction or during individual study time. While third- and fourth-grade students displayed similar emotions they seemed to depend less on the fact that sessions were teacher-led and more on the actual method of teacher instruction, which varied mostly just between grades.

Overall, the majority of third-grade students seemed to be most motivated to learn and to exhibit the greatest signs of enjoyment while participating in multiplication games that involved individual or peer competition, or when learning facts through song and rhyme. While playing a multiplication mastery game where the teacher would pick a student from each row of students in the class to answer a certain multiplication fact first, an audible sad sigh could be heard from students who were not picked. One student not picked to answer a question blurted out rather loudly for the whole class to hear, "darn it!" If none of the students picked by the teacher could answer the multiplication fact correctly it was opened up to the rest of the class. Some students would become so excited and have such confidence they would blurt out the answer immediately, before being called on to respond. The teacher would have to remind students not to yell out the answer so other students could have time to think of the answer on their own. When the teacher told students they would be playing a multiplication game such as bingo, or a multiplication game using dice, students could be heard saying things like "yes, that is fun," or "I like to learn this way." When learning multiplication facts through rhymes or songs, students were witnessed using pens or markers as microphones and playing pretend guitars or drums while singing their facts to an a upbeat musical rhyming tune.

In general, third-grade students seemed to enjoy competitive classroom multiplication activities; however, signs of frustrations or anxiety were witnessed among some third-grade participants primarily during timed or competitive multiplication forms of practice. Some would become visibly upset and pound their fists on the table, or intensely tap their head while trying to quickly recall an answer. These increased levels of frustration and anxiety did seem to affect students' multiplication self-efficacy and performance. For example, during one third-grade multiplication-timed activity a student was observed giving up and sinking back in his chair with a look of despair when he hurriedly gave a wrong answer out loud. Other students were also heard, during this same session, referring negatively to their multiplication performance when they could not think of answers as quickly as other students. For example one fourth-grade student during a timed test seeing that others were finished before him blurted out that he was not good at multiplication because other students were "always were faster [then he was] at getting the answers." He then accused another student of laughing at him for being slow. The other student said that he was not laughing at him. The teacher had to stop the students from arguing and remind them to re-focus on the activity.

Methods of direct instruction where the whole class would listen to the teacher explain various multiplication patterns and procedures were minimal in TLI third-grade sessions. It was during these moments, however, when students seemed to be least engaged in learning. When direct instruction methods were used, both third-grade teachers would continually have to remind students to stay on task, saying such things as “eyes up here,” or “We should not be coloring. We should not be reading. We should not be doing anything but listening.” During some observed direct instruction episodes several students were seen in all TLI groups doing such things as making faces at other students, leaning back on their chairs and rocking, and looking in their desks or around the room. On occasion, both third-grade teachers did redirect students to stay on task outside of direct instructions. For example, one teacher was heard exclaiming, “I want to see all your mouths moving,” while students were practicing multiplication facts through rhymes and songs. One student was also heard saying right before one multiplication activity, “We are doing this again? I am bored of this.”

Fourth-grade TLI students were at times observed experiencing similar emotional responses as their third-grade counterparts. The majority of fourth-graders seemed most excited and motivated to learn when the teachers would switch from reviewing using direct instruction to having the students practice their facts using timed or competitive activities. During observation in one class, after doing a whole class review, the teacher had the students write their multiplication four facts products on a small dry erase board. The students would write them down as fast as they could and then call out “done.” The teacher would then give them their time. The students repeated this exercise several times trying to get faster. During this activity all but one student was observed actively participating. Students were heard saying things like, “I like doing this,” or “Yes, I got faster.” When asked in one session to count down backwards by 4s from 40 in thirty seconds, several students were heard laughing loudly with each other as they tried to race while counting down. During this activity some students were heard making comments like “Yea, I did it!”

During timed multiplication activities, some fourth-grade TLI students also displayed signs of frustration and anxiety. For example, during one timed task one student stopped writing down answers and said, “This is harder now [that it is timed].” During one observation a student, who was unsuccessful at a timed multiplication activity, angrily yelled at another student saying, “You keep laughing at me because I cannot do it!” This student put his marker down and quit trying. Another student said to the laughing student, “How would you like to be laughed at?” During actual written timed multiplication tests, some student’s behaviors included chewing on the end of pencils or hitting their head with their knuckles. One student who did not seem to know very many answers was seen putting both hands over his face and rubbing his head with his fingers. During a timed paper-pencil test given in one study session, one student became very upset when the teacher said, “Time to put down your pencil.” In a very upset tone of voice he exclaimed to the teacher, “But man, I only had one left.” During other observed sessions that involved teachers giving students single fact paper-pencil timed multiplication tests, 2-3 students were always seen giving up or looking at their neighbors test for answers. These students were most often the low-achieving students. However some just seemed to have trouble focusing and the teacher would have to remind these students to continue with their test. As with third-graders, TLI students increased levels of anxiety did seem to hinder some students’ performance and overall self-efficacy.

Some fourth-grade students also displayed signs of boredom and apathy. Similar to third-grade TLI observations, during episodes of whole class learning through direct instruction, the teachers had to repeatedly ask some students, to "pay attention" and remain engaged. During one session a students, seemingly bored with the slow passage of a whole class review, yelled out, "Can I just fill my paper in now?" Furthermore, during sessions in which students were asked to get out their times tables for independent study, some students took an extended amount of time to do so, visiting with their neighbors or rummaging through their desks. During these times at least one-fourth of the class never even seemed to look at or study their times tables, even after they finally got it out. Several students were repeatedly reprimanded for talking to other students about non-related topics during individual study time. For example, in one session during individual study time a student was overheard telling another student all about "a cool" new video game he had recently played. Observations in fourth- and also third-grade TLI sessions seemed to find teachers too frequently spending valuable learning time trying to keep students on task.

Physiological and Emotional States for Third- and Fourth-Grade TA Students

Qualitative data found third- and fourth-grade TA students excited and eager to play TA. Timez Attack game play features seemed to motivate students to want to practice and learn multiplication facts in a fun, enjoyable learning environment. Unlike some third- and fourth-grade TLI participants, TA students continually remained focused throughout their sessions and students spent the entire 20 minutes engaged in TA game play. The classroom teacher was never heard having to remind students to stay on task. A few third- and fourth-grade students occasionally showed signs of tension and frustration. This frustration seemed to do with technical aspects of the game and only rarely had connections to a student's multiplication learning and/or abilities.

Third- and fourth-grade students displayed their enthusiasm for TA game play with comments like, "Is it my turn?" or "Yes, it is my turn now!" One third-grade student was heard yelling, "I do not want to get off!" Both third- and fourth-grade TA students would complain when they were told their session was done by saying things like, "I need more time so I can get to the next level," or "Let me just stay on until I finish this part, please, please!" Students not playing the game would watch the time if they were next. One student waiting for a turn at TA yelled out, "Hey it is 12:31, it is my turn!"

When third- and fourth-grade participants were asked why they seemed to be enjoying playing TA, students would make responses such as, "It's awesome," or "It is a fun way to learn my multiplication," or "It is fun and it helps me." One fourth-grade student said, "It is fun to run around in the game." Another fourth-grade girl said she hated math, but loved "this," referring to playing TA. A third-grade student stated that playing TA made her feel good because, "It keeps me focused and I have better control of what I am thinking." Another third-grader responded that playing TA made her feel happy that her brain was concentrating. Fourth-grade students also made similar comments. For example one fourth-grader said that learning her multiplication facts through TA game play made her feel "good because they [multiplication facts] stay in my mind better, because it [TA] makes you do them over and over again until you know them."

Students appeared totally absorbed while playing TA. They would often yell out answers, clap their hands when they got the answers right, or make comments out loud such as, "I got it right," or "I have to do it again," or "Yea, I pass a check point." Both third- and fourth-grade students were heard skip-counting along with the game. One third-grader was observed talking to the computer throughout his entire game play session. He would make comments like, "That was easy," or "Oh, all done." This same student would kick his own feet every time he would have his TA character jump. When asked why it looked like he was concentrating so hard, a fourth-grade TA student said that he had missed some hard ones, and now wanted to get them right. One student said he wanted to try hard to pass all the levels quickly so he could then play TA division. Another student was heard telling the student next to her that she really needed to go to the bathroom but did not want to stop playing the game to go. Students never had to be reminded by their teachers to stay on tasks and no students were observed disrupting other students during game play.

Coding of MAS open-ended responses (see Appendix E) reaffirmed that students enjoyed learning facts with TA game play. MAS written answers found (unlike in TA pre-survey and both TLI pre- and post-survey responses) no TA students feeling learning multiplication facts to be dull or boring. Regarding students feelings toward learning multiplication facts or when they thought learning facts was most enjoyable, MAS post-survey comments included, "I really feel good when I am playing Timez Attack," or "[When] playing Timez Attack, [because] I want to do my best and learn them easily," or "[When playing] Timez Attack. It is a fun challenging game for me." Out of the 32 TA post-survey responses that referred to activities as being an enjoyable way to learn multiplication facts 23 students specifically mentioned TA.

Some students did at times seem frustrated or anxious while playing TA. Students were heard saying things like, "These controls are messing me up," or "These dragonfly dudes are hard to get," or " I cannot get out of the lava!!," or "No I meant to type in 60, gosh," or "I hate it when I know the right answer and type it in wrong," were heard from both third- and fourth-grade TA subjects. One student became very upset when she accidently typed in an 18 and meant to type a 16. She calmed down when she realized the computer gave her a second chance. Several students, mostly third-grade students, made comments regarding the fact that they knew the answers but could not type them in fast enough. TA students remained motivated to play TA even when they became frustrated with some aspects of game play. At times, however, more technical issues associate with game play did take away from students' time in learning facts through game-play. One special education student became extremely frustrated when he felt he could not pass a level because he could not type fast enough. This student ended up having a teacher aid type the answers for him. When students were asked if TA game play made them nervous, some students responded with comments like, "I do not like TA when I am timed." Only two out of more than two-dozen third- and fourth-grade subjects, however, stated that at times game play made them anxious enough that they thought about not playing TA. One student said, "Being timed tested in TA does not bother me, it makes it a challenge, I like a challenge." Another student when talking about being timed tested in TA said, "I think more clearly during it than when using things like flash cards, I can see the answers instead of the my mind going blank." Another student who was typing multiplication answers very intently and looked anxious kept saying, "I can do this, I can do this, Yea, I got to the check point!" One student on his post-MAS responded to how learning his multiplication facts made him feel by even stating that he was "happy and not as scared now with Timez Attack."

Vicarious Experiences for Third- and Fourth-Grade TLI Students

For both third- and fourth-grade TLI participants, their peers successes and failures seemed to be most apparent to them during competitive modes of practice. This was probably due to the fact that this is when students were most likely to hear others' responses and observe other students' written work. During these times students heard other students say things like, "Yes, I did better this time" or, "I finished more of the problems this time," but they also heard thing like, "I don't know the answer." During these times students were noted as recognizing their peers' accomplishments. One student was overheard saying to a student sitting near by "you are good at multiplication." Another student was heard telling a classmate "you always know the right answer." Fourth-grade students would especially look around to notice who finished a timed competition or test first; however, during one observation one student told another to "quit looking at [his] paper!" In another instance, when students tried to write the product of a specific fact family as quickly as they could, two students got in a verbal fight as to who finished first.

Multiplication competitions and games were also times when students seemed to be most likely to share knowledge of their abilities with others. One third-grader, competing against another student in a multiplication game using dice, was heard sharing his knowledge of multiplication in order to help the other student figure out the answer. He stated as she sat looking perplexed "just count by two's." Similar situations where students helped other students arrive at a correct solution were seen among fourth-graders. One fourth-grader noticing that his neighbor was having problems filling out a particular multiplication pattern sheet was heard reminding that student of properties specific to that fact just recently taught to them by their teacher.

As noted earlier, the learning environment surrounding individual or peer competitive activities and tests did not always produce a positive learning experience for every student. It was during these times that others were also made aware of their peers' failures. This was shown through, as previously discussed, the fourth-grade student who was laughed at by another student for not finishing a multiplication task in the allotted time. When students were asked if it bothered them if some students performed better at a specific multiplication activities than they did, the responses were mixed. Some students referred to being “glad for the other students,” while some said “it did not matter who was better as long as they were all having fun.” Others referred to it as making them feel like they could do better, while others students referred to it as making them fell “bad,” “sad” or “jealous.” It seems that the students’ ability to know how other students were doing during class activities provided mixed motivation for the students.

These mixed feelings were also found in both TLI third- and fourth-grade students’ responses to MAS open-ended question 28 (“When I see other kids do well at learning their multiplication facts it makes me feel…because…”). This was true on both the pre- and post-survey. Some negative comments included “Left out,” or “Like I am bad at it, because they have a better score.” Negative comments were fewer on both TLI third- and fourth-grade post- over pre-survey responses. Also, more third- and fourth-grade TLI students in their post-survey written response felt encouraged to do better themselves seeing their peers succeed in the post survey with comments like (see Figures 8 and 9). Some students responded with comments like “Good because if they are learning I know I can learn,” or “[lt makes me feel] like I want to do better.”

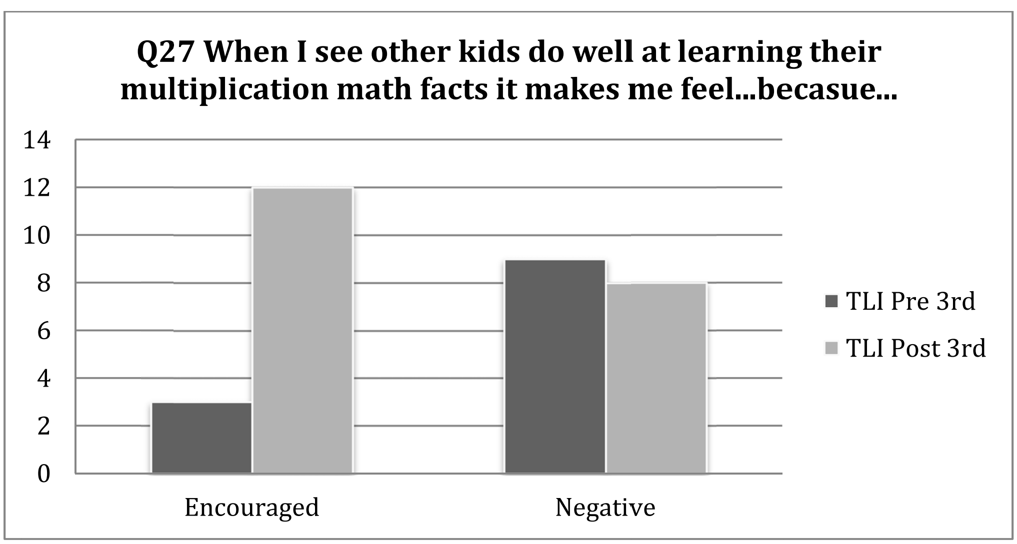

Figure 8. TLI third-grade encouraged and negative pre- and post-MAS responses to Q27.

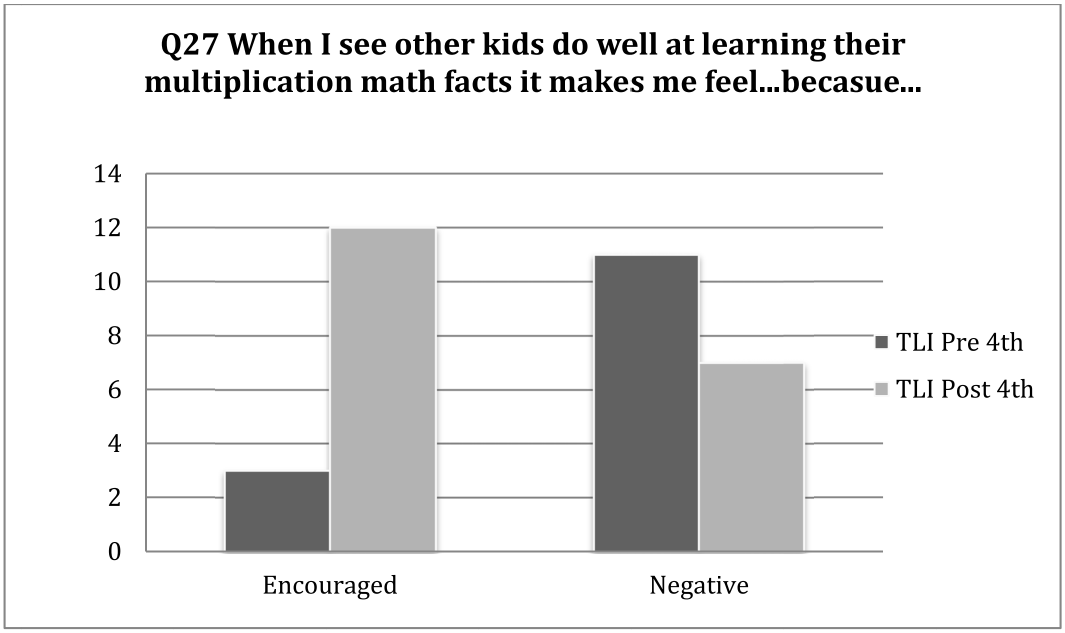

Figure 9. TLI fourth-grade encouraged and negative pre- and post-MAS responses to Q27.

Vicarious Experiences for Third- and Fourth-Grade TA Students

Third- and fourth-grade TA students' vicarious experiences seemed to be similar. Overall, however, they seemed to be less concerned and aware of each other's multiplication performance than did their TLI counterparts. In general, both third- and fourth-grade TA students seemed to be more curious about how other students were advancing through the game on a more tactical level than from an academic viewpoint; however, some students did make comments that revealed knowledge of other students' multiplication success due to TA game play and responded favorably when speaking of other students' multiplication mastery through TA game play.

Third- and fourth-grade students' were primarily observed looking at each other's screens when first loading the game or when there seemed to be a pause in their game. If allowed, some students who were not playing would come and watch others play TA. Students' verbal interaction in both grades seemed to revolve mainly around TA game play. If students knew another student had been through the level they were on, they would sometimes ask that student specifics about maneuvering through that level. Sometimes students would just ask out loud if anyone knew how to maneuver through a specific area in the game. For example, one third-grade student yelled out while playing, “Someone tell me where the key is here.” One fourth-grade student was heard asking another student sitting next to him, “Where do I go next?”

Similar to TLI students, TA students had mixed feelings when answering how they felt if they knew other kids were better at learning their multiplication facts. TA students’ negative and encouraged MAS-survey written responses in regards to peers’ success in learning multiplication facts were very similar and in some cases the same as TLI students’ written comments. Also, Like TLI students both third- and fourth-grade TA students written survey response reveled less students having negative feelings toward peer’s success after intervention. (see figures 10 and 11).

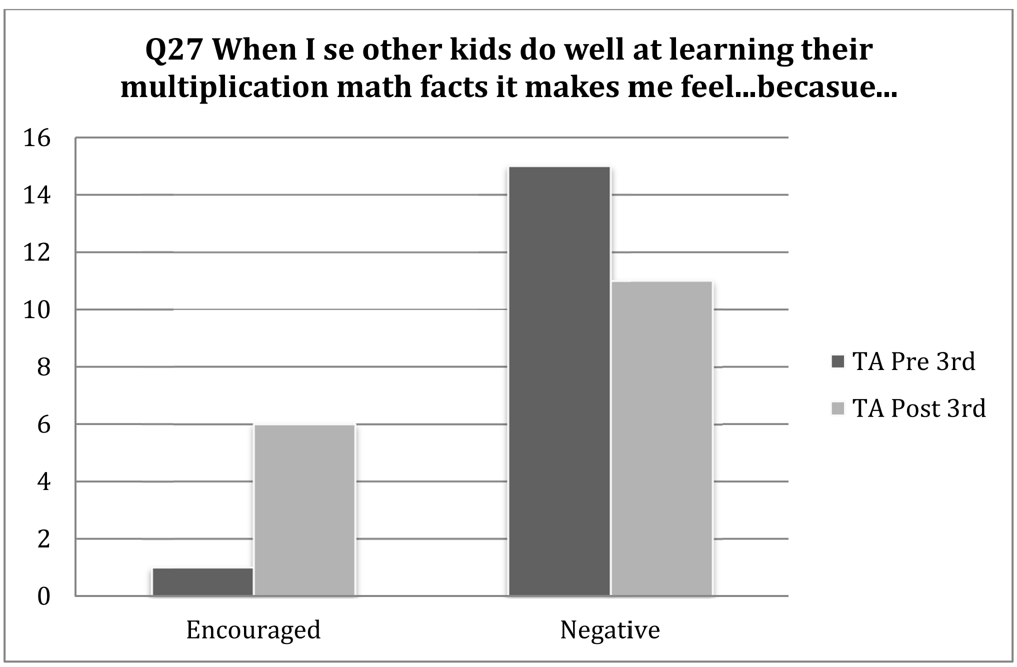

Figure 10. TA third-grade encouraged and negative pre- and post-MAS responses to Q27.

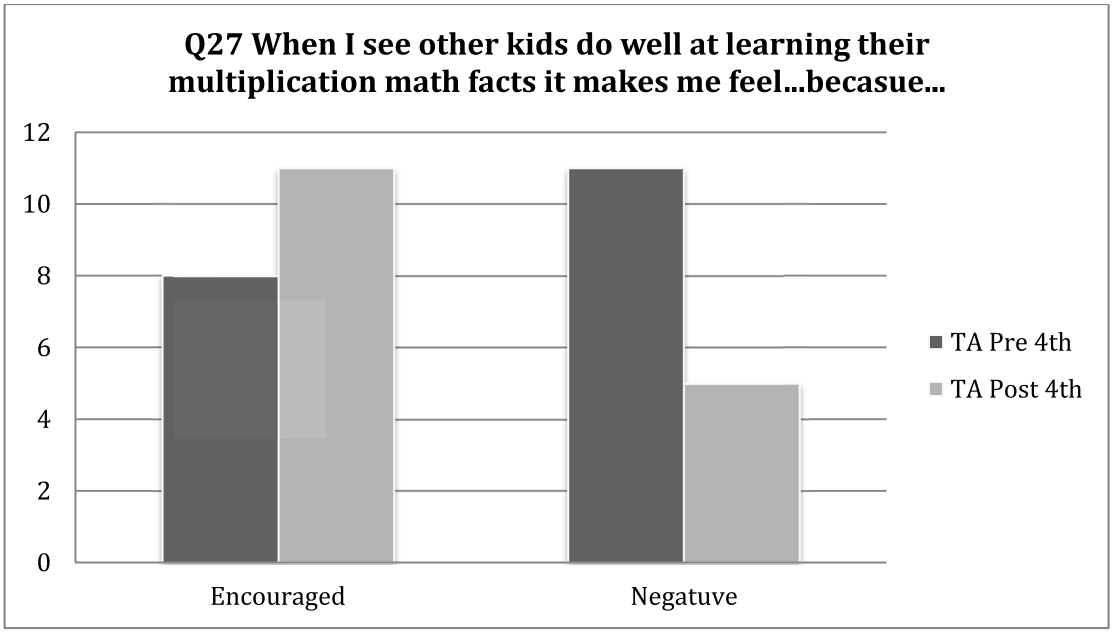

Figure 11. TA fourth-grade encouraged and negative pre- and post-MAS responses to Q27.

When TA students were asked how they felt if they knew other students had advanced through Timez Attack more quickly than they had, TA third- and fourth-grade students seemed unconcerned that there were students at various higher and lower levels in the game. For example, one third-grade student remarked concerning another student at a higher level in the game, "I like to just care how I learn." More than one fourth-grade student mentioned that they were just "happy" for students that were doing well at the game. One student remarked that he was glad that the game helped others as much as it did him. Another student remarked, "It is okay if they are farther in the game [TA], they might just know more than I do yet, so they may be speeding through it." Only one student out of at least 25 asked remarked negatively, indicating that it made her feel a little sad to see others doing better at the game, but she did not know why. It seems students may have somehow separated being good at playing Timez Attack with multiplication mastery. In fact seeing students at higher levels seemed to be motivational. Both third- and fourth-grade students were heard commenting on wanting to advance to a higher level. For example, one student glancing at his neighbors screen before he started game play said, “Cool, I want to get there.”

When third- and fourth-grade students were asked if they thought TA was helping the other students in the class, some students were not sure. Others students responded saying they thought TA was helping. One third-grade student when asked this questions said, “Yes, like this guy, (pointing to the boy next to him) he knows things now like 3 x 3 = 9 and 2 x 4 is 8.” Another simply just said, “They are getting better now they are practicing.” A fourth-grade student actually gave two names of students she knew whose multiplication mastery had improved since playing.

Social Persuasions for Third- and Fourth-Grade TLI Students

Throughout the third- and fourth-grade TLI sessions, there was evidence of teachers encouraging and praising students for their efforts and abilities. Students overall seemed to appreciate teachers feedback, and it seemed to provide the extra encouragement some students who were struggling with multiplication mastery seemed to need. Students were seen smiling and looking pleased or saying “thanks” as teachers said things like “good job,” “wow,” or “I knew you would do better this time.” When asked if they felt their teacher encouraged them to do better, all third- and fourth-grade students responded affirmatively; however, there were some differences noted between third- and fourth-grade practice sessions in regards to teacher-to-student communication.

Third-grade teachers seemed to provide immediate feedback to student learning more effectively than did fourth-grade teachers. Third-grade session students seemed to primarily involve verbalizing multiplication practice and learning through class games, singing songs, reciting rhymes, and other non-paper pencil activities. Fourth-grade teachers on the other hand tended to use more written practice modes. Encouragement and responses were often not given until a test was completed and corrected. In one fourth-grade class the teacher always corrected student's timed tests and then handed them back during the next multiplication practice session. These differences became more apparent when students were asked what their teacher did that most helped them learn their facts. Third-grade students referred to the rhymes or songs their teacher sang and to letting them have multiplication "races" and play "fun games." Fourth-grade students, on the other hand, often referred to paper-pencil practice. For example, one fourth-grade student response to how her teacher helped her learn best referred to having her teacher give her paper-pencil timed tests over and over. Another fourth-grade student just stated, "he was glad his teacher just kept helping him even when according to the student "I did not know them." No matter the methods, teacher encouragement and feedback seemed to be beneficial to students.

Social Persuasions for Third- and Fourth-Grade TA Students

Unlike TLI subjects, TA students in both grades had very limited interaction with their teachers during TA sessions. Teachers were able to monitor students' progression through TA game play online and were heard at times commenting on a student's level of game play before the students began his or her intervention session. On occasion, in both grades, the teacher would walk past the students playing TA and say things like, "Wow, good job. You are already at your 7's." When asked, some third- and fourth-grade students responded that they felt their teachers and others thought they were getting better at their multiplication facts since playing TA, while other students were unsure. A fourth-grade student observed during her 10th session stated, "My mom wanted to see if playing TA helped. She was surprised I knew them [facts 0-12] now."

Performance Experiences for Third- and Fourth-Grade TLI Students

Overall third-grade and fourth-grade students generally seemed to feel that their multiplication abilities had improved through TLI. Third-grade students that were actually asked if the multiplication activities they did in class helped them remember their facts all felt they did; however, some students felt they sometimes needed more time to think through or respond to a multiplication question. Most fourth-grade students that were asked this same question also felt that TLI multiplication practice sessions had helped improve their multiplication performance, although there were some who felt their teacher-led sessions had not.

Third-grade students were often seen mouthing a multiplication fact rhyme or song, or skip counting when they were asked to recall a specific fact. One student remarked that playing multiplication games helped him “want to practice his multiplication facts.” Students observed in the 7^{th} session that were being timed to skip count from 0-36 in under 4 seconds remarked that they were faster then they use to be. One row told the teacher to pay attention to their row because they could “all now do it under 4 seconds.”

Some third-grade students alluded to needing more time to complete or think through a correct response during whole class activities as a result of other students finishing before them and yelling out the answers. For example, when racing to see which row could correctly represent multiplication facts with groups of beans first, the conclusion of a round left some students not finished before the answer was given. Some students would then not finish their task, while others continued to work out problems on their own not looking up while the teacher drew the answer on the board.

Overall the fourth-grade students asked, felt TLI sessions had helped them. Comments from these students included things like, “I use to not know my times, now I see patterns and I know it good," or, "it" [reviewing with my teacher] "just makes me better now." One student commented that her class used to only practice together, but now they studied on their own and she thought that was better. Also referring to individual study time, one student said it helped because you could "just learn them as fast as you can." One student said timed tests helped because, "it is funner and feels like a game." He noted the timed multiplication tests his teacher gave him helped him because he was "racing to get as fast as [he] can." At least 4 other students questioned indicated that paper-pencil timed multiplication practice helped because you could see if you were getting better.

While most TLI students asked were positive toward TLI practice sessions, there were those who were not. One fourth-grade subject referred to being bored during sessions because she already knew her facts. Referring to timed paper and pencil multiplication test, one student flat out said it did not help and that she did not like to practice them that way or any way. Another said timed paper and pencil multiplication practice bothered him because it made him "not feel smart."

Performance Experiences for Third- and Fourth-Grade TA Students

Observations and comments made between both third- and fourth-grade TA students did suggest that basic multiplication math fact performance improved while learning within the self-evaluated, self-paced TA environment. Students' comments also revealed that TA game play provided them with a more positive learning experience than other methods they had used.

Both third- and fourth-grade students were observed progressing through the game, although fourth-grade students, probably due to the fact that they had been taught their 0-12 facts previously as third-graders, progressed at a much faster pace. No third-grade students progressed successfully to the end of TA; however, many of the fourth-grade students were successful. Also, unlike their fourth-grade counterparts, third-grade students often complained that they needed longer sessions in order to successfully advance all the way through a level.

All of the third- and fourth-grade students asked responded positively when asked if they felt TA helped them learn their multiplication facts. Many students mentioned that while TA was fun, it also helped them learn. One fourth-grade student stated that, "Timez Attack helps me learn times problems I did not know before. I like math more now because I know more of the answers and I can learn as much as I want, and I don't have to wait for the teacher." Another third-grade student said, "It was way easier than learning on paper. You get to throw slugs to learn the answer." Several third- and fourth-grade students mentioned that it somehow made their "brain work better." One student stated that during game play, "I count up twice to see the answer, then I stick it in my brain, then when the test comes it is stuck in my brain." One student said, "I used to be bad" at multiplication, but "now TA helps me memorize them." After finishing a level, another student said, "Everyone already thought I was good. Now after playing TA, I am even better."

Several third- and fourth-grade students acknowledged TA's self-paced and self-evaluative components to be a benefit in their learning. One student, when talking about learning from TA game play stated, "It stays in my mind better. You go over it and over it until you get it." Another stated that she felt TA was fun, but it also let you go over and over multiplication facts until you learned them. Other comments included, "It is better than learning with a teacher because if you got it wrong you know right away and you can go as fast as you want," and "TA is better than learning with my mom or teacher because you can go at your own pace." Other's mentioned that they felt TA helped them learn because it kept making them retry until they got the answers right. One comment made was that TA gets "harder and harder, which makes you learn." Another student said that he always learned from TA and only sometimes learned from teachers. Another said that her mom made her practice with flash cards at home, but that she would just look on the back of the card for the answer. When compared to other strategies, one fourth-grade student felt that "the best way to learn multiplication facts is through playing TA, [because] TA helps you become quick and fast." Another fourth-grade student stated, "I play TA because it helps me learn and is not boring."

Summary of Qualitative Findings

Overall physiological and emotional responses from third- and fourth-grade TLI and TA students were more positive than negative; however, subjects' level of engagement and enjoyment in learning fluctuated significantly more within TLI's instructional environment than it did in TA's. Unlike TLI subjects, TA participants never seemed "off task," and never appeared or spoke of being bored. Students' responses to open-ended questions from the post-MAS supported findings from observations and interviews as students specifically mentioned TA as an enjoyable method for learning basic multiplication facts. There were some students in all study groups who at times showed signs of frustration and nervousness. For TA subjects, these negative emotions usually resulted from tactical and technical issues or during timed testing. TLI's negative emotions seemed to result more from a learning environment that sometimes allowed for negative student interaction, like when students provided incorrect responses in front of peers during timed or competitive activities

While all study group teachers were heard encouraging and praising students, as would be expected, TA's instructional environment had far less interaction and social support from teachers. TA teachers were able to keep track of student performance online and did at times recognize students' multiplication performance in relation to having advanced to various levels of the game, but overall TLI learning environment provided students with greater opportunities to experience social support from teachers

Vicarious experiences between TA and TLI's instructional environments also varied. As previously stated, TA students seemed to be less concerned and aware of each other's multiplication performance than did their TLI counterparts; however, TA participants were seen occasionally glancing at each other screens and noticing other student game level. While students from TA and TLI groups similarly reported both positive and negative feelings in regards to how others students multiplication performance affected them, all but one TA student responded positively towards some peers having advanced more quickly through TA levels of play. Students' written comments on the pre- and post-MAS did find both TA and TLI students feeling more encouraged and less negative regarding peers accomplishments after intervention then prior to it

Regarding performance accomplishments, some evidence of students increased mastery through both TLI methods and TA game play was observed. All TA students asked felt positively that TA game play had improved their multiplication mastery. TLI students, however, remarked both positively and negatively in regards to changes in their multiplication performance due to TLI methods.

CHAPTER VI: DISCUSSION AND CONCLUSIONS

In this concluding chapter, a summary of findings in relation to my research questions are discussed and implications regarding these findings are then explained. Next limitations and suggestions for future research exploring the impact of CAI on students' abilities and academic self-efficacy are given followed by my final conclusion.

Discussion of Findings

The main purpose of this study was to explore the impact that learning within a motivational, self-paced, and self-evaluative CAI environment linked to teacher instruction can have on third- and fourth-grade students' multiplication mastery and self-efficacy. This was accomplished through the analysis of my four research questions. A discussion of conclusions drawn from this analysis follows.

Research Question 1: To what extent does TA game play affect multiplication mastery among third-grade and fourth-grade elementary students?

Similar to other educational video game software packages shown to positively impact students' mathematical reasoning, problem solving, and pre-algebra and algebra skills (Kebritchi et al., 2010; CGTV, 1992), this study found educational video games, specifically Timez Attack, to be an effective method for improving elementary-age students' level of multiplication mastery. Statistical comparisons of TA students' 100-item 2-10s two-minute timed multiplication pre- and post-tests found on average that both third- and fourth-grade TA students' speed and accuracy in solving basic multiplication facts improved after intervention. Fourth-grade students on average went from 29.8 to 49.62 facts answered correctly after TA sessions with third-grade students having almost 100% increase in their scores (13.62 to 26.28). As third-grade post-test scores were similar to fourth-grade pre-test scores, it is plausible given an additional 12 intervention experiences third-grade students might have quadrupled their original average scores to match fourth-grade TA post-test scores. Additional practice session may likely produce even greater levels of student mastery.

Qualitative findings also supported quantitative findings. Observations found students advancing through TA multiplication-leveled play, with some fourth-grade students successfully progressed all the way through the 12's level of play. Students not only commented that they enjoyed playing TA because it was fun, but also because TA's motivational, self-paced, and self-evaluative instructional environment helped them learn and remember their basic multiplication facts.

A recent study conducted after the completion of my pilot study and after commencement of my current study found that TA significantly increased student performance (Jones, 2011). This single subject pretest post-test study was conducted later in the school year. Therefore, the study's 70 third-grade elementary-age student participants, unlike the third-graders in my study but similar to the fourth-graders in my study, had been previously taught their 0-12 multiplication facts. These subjects were given an average of one hour a week for sixteen weeks of additional multiplication practice through TA game play. Pre to post T-test analysis found TA intervention to improve students' computational achievement in multi-digit multiplication, division, and algebra skills. This study was different than mine in that it had no comparison group and did not test specifically for multiplication mastery; however, multiplication mastery, as mentioned previously, is foundational to more complex mathematical skills like those tested in Jones's study (Elkins, 2002; National Research Council, 2001; Woodward, 2006). This was revealed in my study as one student, when asked if playing TA helped him to master his facts, stated yes and that now that he knew his multiplication facts, "I figured out that I can do good at division. It is just multiplication backwards." One might assume that students from the Jones's study, who improved these more complex mathematical skills, would have also improved their level of multiplication mastery through TA game play similar to my study.

Research Question 2: To what extent does TA game play affect multiplication mastery when compared to teacher-led instruction?

Similar to findings from Williams (2000), statistical comparisons between fourth-grade TA and TLI pre- and post-test mean multiplication scores found CAI, specifically TA, to be more effective then TLI in improving student multiplication mastery. Initial multiplication pre-test comparisons found no significant differences between fourth-grade TLI and TA multiplication scores. Post-test comparisons between fourth-grade classes showed TA participants to significantly outperform their TLI counterparts by answering over 50% more problems in the same given time. Fourth-grade TA subjects increased their average multiplication post-test scores by twenty questions compared to only nine questions with fourth-grade TLI subjects.

Third-grade TLI and TA groups' multiplication mean scores, like scores between fourth-grade TA and TLI groups, had no initial significant differences prior to intervention. Similar to pilot study findings, analysis comparing post-test multiplication mean scores between third-grade TLI and TA students still found no significant differences in number of correct responses, Examination of qualitative data provided possible causes for the similar performance between third-grade TA and TLI students and differences between fourth-grade TA and TLI students' post-test performance. TLI and TA third-grade students seemed to have experienced a more similar learning environment than did fourth-grade TA and TLI subjects. Field notes taken during observation found TLI study sessions to be similar within grades, but vary between grades. While fourth-grade students' learned primarily through direct instruction and paper and pencil practice, third-grade TLI subjects were provided a more multisensory learning experience, through singing, rhyming, and multiplication games. Somewhat similar to TA's features, third-grade TLI students practiced their facts either orally or through multiplication activities and games. This made it easier for third-grade students to quickly identify and correct multiplication errors compared to some fourth-grade paper and pencil practice methods where students had to wait for the teacher to correct their responses.

Furthermore, similar to other CAI research (Moss 2004), observations found that overall TA subjects seemed to remain on task during the entire 20 minutes of TA game play. Recording of TLI practice session episodes found that students were least focused and when learning or reviewing multiplication properties through direct instruction and individual "quiet" study of the 12 times tables. Observations of TLI third-grade practice sessions found no evidence of "quiet" individual study and far less moments of direct instruction than fourth-grade TLI students experienced. Therefore more TLI third-grade than TLI fourth-grade students seemed, like all TA students, to be learning and practicing facts during the entire 20-minute study session.

Additionally, collection of data began during the second month of school, before third-grade students had begun working on their multiplication facts. Third-graders who had been at the school the previous year had been introduced to multiplication as repeated addition at the end of their second grade, but were only taught their 0's, 1's, 2's, 5's and 10 facts. Third-grade students' were therefore learning most facts for the first time, and the length of the study session allowed the majority of third-grade TA students not to make it passed their 6 times facts. Third-grade TLI students, however, were taught their facts through the 10s. Given these conditions it was actually surprising that third-grade TLI students did not significantly outperform TA third-grade students. It may be that while TLI students were taught all the facts appearing on the post-test, they may not have been able to recall them as quickly and accurately as whatever amount of facts students learned and practiced through TA game play.

Fourth-graders, unlike third-graders, spent a majority of the previous school year learning all their basic multiplication facts. This allowed TA fourth-graders to either skip or advance more quickly through TA levels of multiplication facts. This also may be why among fourth-graders TA game play was more effective in improving levels of multiplication than fourth-grade TLI methods. While TA subjects were able to quickly pass off facts they already knew and focus on facts they could not yet quickly recall, student comments found some fourth-grade TLI students frustrated in having to spend class time re-learning multiplication properties and reviewing facts they had already mastered.

As it was unsure at the onset of the study how many facts TA and TLI students would have time to review, learn and practice during the allotted study sessions time frame my study did not measure mastery at any given level, but looked only at students ability to increase their speed and accuracy in solving basic multiplication facts 2-10. When using study teachers' measurement of approximately 2 seconds per problem to test for mastery, however, fourth-grade TLI had 17% more and fourth-grade TA had 30% more of the groups' students post-test scores reach at least this level of mastery then did on pre-test scores. TA third-grade group had one and TLI had no students achieve mastery at this level after intervention. This is not surprising as third-grade students were just learning their facts. Fourth-grade students had been taught all of their basic facts the previous year and did not have to use study session time to learn facts but could instead use this time simply improving speed and accuracy in solving facts. In the given study time frame, however, TA over TLI helped a greater percentage of students obtain mastery at 2 seconds per problem on the 2-10s facts test.

Despite possible contributing factors in final performance scores, analysis of third-grade TA and TLI data revealed that learning through TA game play is at least as effective as some TLI methods. It can at times, as was the case with fourth-grade TA students, even be more effective then some TLI methods, especially when TA is used in addition to students having been previously taught facts in a more traditional teacher-led learning environment.

Research Question 3: To what extent does TA game play affect multiplication self-efficacy among third-grade and fourth-grade elementary students?

Overall, TA's software computer features supported other research, which found that both academic abilities and attitudinal beliefs simultaneously improve as learning takes place in some CAI environments (CTGV, 1992; Kuliks, 2003). This study also supported self-efficacy research that has shown a positive correlation between mathematical performance and self-efficacy beliefs (Pajares & Kranzler 1995).

Analysis of fourth-grade pre-MAS to post-MAS revealed TA game play to be effective in improving students' self-efficacy beliefs. Analysis of the MAS self-efficacy scale revealed TA fourth-grade students having overall statistically significant ($p < .05$) increased multiplication self-efficacy beliefs after intervention. Looking specifically at individual self-efficacy questions, fourth-graders TA mean response to MAS question 1, "I am sure I can master the multiplication facts taught to me in class this year," rose significantly from 3.9 to a stronger agreement of 4.51. Fourth-graders TA average responses to self-efficacy MAS questions 3 and 4 also raised significantly from 4.17 to 4.55 and 3.86 to 4.54 respectively.

Third-graders TA mean pre- to post-survey self-efficacy scale scores went from a mean score of 3.84 to 3.92. Analysis of MAS Likert-type items, however, found no significant improvement in regards to self-efficacy beliefs after intervention within third-graders TA self-efficacy scores. This was true when comparing pre- to post-survey item scores individually or collectively by scale factor. The fact that fourth-grade TA subjects showed significant increased feelings of self-efficacy while third-grade TA subjects did not may be due to the fact that fourth-grade TA subjects multiplication post-test scores were significantly higher than third-grade post-tests. As mathematical ability and self-efficacy have been positive correlated (Pajares, 1999), it is not surprising that fourth-graders over third-graders self-efficacy beliefs showed a greater increase.

Furthermore features of TA game play seemed to positively impact some factors, which may influence self-efficacy. Qualitative findings revealed that overall third- and fourth-grade TA students were engaged and enjoyed their intervention experience. Student comments and answers to short response questions found that students were also confident that TA game play was improving their own and other students' level of multiplication mastery. Student coded episodes did occasionally find they were experiencing frustration and nervousness resulting from TA game play. Pre- to post-MAS Likert-type responses however showed a significant decrease within fourth-grade TA participants' nervousness in learning new multiplication facts after intervention sessions. This finding supported Wittman et al. (1998) who recommended that CAI could provide a learning environment that effectively reduces some students' level of anxiety when learning basic multiplication facts. Other statistical significant findings between third- and fourth-graders after TA intervention included fourth-graders increased motivation to learn and awareness of other students' improved mastery and third-graders increased enjoyment in learning.

Finally, self-efficacy findings from this study supported Jones' (2011) study, which also explored self-efficacy changes in students learning through TA game play. Paired T-test comparisons and non-parametric statistics of Jones' seven item pre- and post Likert-type general mathematical self-efficacy survey found significant increases in students' post-survey responses to their general mathematical self-efficacy beliefs after TA intervention sessions; however, questions used in Jones' self-efficacy survey were actually from an existing mathematical self-confidence survey and were not changed to better reflect self-efficacy's theoretical meaning. Mathematical self-confidence and self-concept are often used as synonyms for self-efficacy. These constructs though somewhat similar but lack the specificity and theoretical foundation of self-efficacy. Self-confidence is considered a reflection of one's competence ("I'm good at math") and includes feelings of self-worth accompanying competence beliefs. Self-efficacy, on the other hand, concerns ones judgments about perceived capabilities ("I'm certain that I can master mathematical concepts taught to me in school this year) (Klassen & Lynch, 2007). The five self-efficacy survey questions used for my study were adapted from an actual mathematical self-efficacy survey and better reflected a valid self-efficacy assessment. Therefore, my findings provide more sound theoretically support to Jones' conclusion that modern educational games can have a positive impact on overall mathematical self-efficacy beliefs.

Research Question 4: To what extent does TA game play affect multiplication self-efficacy when compared to teacher-led-instruction?

Pre- and post-MAS comparative analysis used to assess differences in multiplication self-efficacy beliefs between third-grade TLI and TA groups and fourth-grade TLI and TA groups found significant differences in some questions that did not initially exist. These differences were favorable among fourth-grade TA student over TLI student, but the reverse was true among third-grade groups.

Analysis of MAS scales found no significant differences between fourth-grade TA and TLI pre- or post-survey mean response scores. Analysis of MAS individual items did find TA students to be significantly less nervous then fourth-grade TLI subjects when learning new multiplication facts and more confident in their multiplication mastery performance. Recorded observations also found fewer TA students seeming to exhibit nervous emotions in regards to multiplication performance compared to TLI students. Timez Attack software features provided multiple opportunities to respond and immediate feedback in a motivational, self-paced learning environment not found in most of the fourth-grade teacher-led methods. This difference may have contributed to some TA students reporting lower anxiety in mastering new multiplication facts (CTGV, 1992, Wittman et al., 1998; Moss, 2004; Wilson et al., 1996). In addition, lower anxiety and more positive feelings toward multiplication performance have been shown to increase students' self-efficacy beliefs (Bandura, 1997).

Comparison between third-grade TA and TLI pre- and post-MAS self-efficacy scale's overall mean scores found third-grade TLI over TA students having significantly higher self-efficacy beliefs after intervention. Analysis of individual MAS items found third-grade TLI over TA students responding significantly more positive to three out of five self-efficacy and two out of three social persuasion questions. This may have been impacted by the fact that both qualitative and quantitative findings found third-grade TA's learning environment provided less opportunities to receive positive social persuasion from teachers while attempting to master facts than did third-grade TLI's. While some of these differences were also found between the learning environments of fourth-grade TA and TLI students, students had already experienced traditional classroom learning of their basic multiplication facts the prior year. Social persuasion received through TA game play may have been insufficient for third-grade TA subjects when compared to other groups with regard to impacting self-efficacy beliefs. Similar to performance results, TA may be most effective when used in addition to other more traditional teacher-led methods.

Implications

Findings from this study have implications for those looking at implementing or creating both CAI software programs and non-CAI learning methods.

Computer-Assisted Instruction

Findings from this study suggested CAI like TA, designed to help students develop proficiency and knowledge, seemed to offer a fun and motivational learning environment improving student performance. Implementation of CAI is therefore worth consideration among educators and parents. Those who are looking to incorporate CAI as a means to improve students' multiplication mastery and other academic abilities should consider the motivational, self-evaluative, self-paced features, which seemed to make TA most effective when choosing a software program. Findings also have value for designers considering what features to include when hoping to create successful educational software programs.

Furthermore, results from this study found TA game play had more of a significant impact on improving students' level of multiplication mastery and self-efficacy in TA fourth-grade students compared to TA third-grade students. Fourth-grade TA students, unlike third-grade TA students, had already been taught all of their basic multiplication facts the previous school year and had subsequently already experienced significant amounts of TLI multiplication practice, similar to those discussed in this study. It seems that TA may be most effective when used in addition to other modes of practice including TLI. Computer-assisted instruction, in general, might also have the greatest positive impact on learning and self-efficacy when used as a supplement to and not a replacement of TLI.

NON Computer-Assisted Instruction

This study also found that, among third-grade students, TLI learning environments were as effective as the TA learning environment in improving students levels of multiplication mastery, and perhaps even more effective in regards to self-efficacy. The learning environment of third-grade TLI classes in this study provided multi-sensory activities that seemed to motivate and engage student learning similar to TA. Educators who find themselves in schools where financial or technical resources do not allow access to multiplication CAI software programs like TA may be able to improve multiplication mastery and self-efficacy as they consider using and creating learning methods which provide an engaging motivational, self-paced, self-evaluative learning environment similar to TA's.

Limitations

It is difficult to know how much increased levels of multiplication mastery in TA subjects were due to specific features of the game and how much was due to increased multiplication practice time in general; however, the fact that performance did improve does demonstrate that TA game play was time on task and was not just time playing a fun video game. Also, TA fourth-grade students' mastery did improve significantly more than their TLI counterparts. Other limitations associated with this study fell into three categories: (1) insufficient intervention time and (2) lack of equal intervention time (3) MAS research instrument.

Insufficient Time

The number and length of TA intervention session was not adequate for many students to advance through all levels of play, especially third-grade students. If students had been given a sufficient amount of practice sessions, or at least the opportunity to have some game play at each level, results may have been more favorable in regards to TA game play. All third-grade TLI students, unlike third-grade TA students, were given the opportunity to learn their facts through at least the10s.

Students began TA sessions with various video gaming experiences. Students whose video game play was minimal may have had a harder time and taken longer just maneuvering through the game. These students also would have benefited from longer and more intervention sessions.

Equal Time

Students that were absent from TA sessions were more often able to make up the sessions than students absent from TLI sessions. Therefore, there may have been more TLI students who did not receive all 12 of their TLI practice sessions. The fact that TA sessions were easier to make up because TA did not require additional teacher time can, however, also be seen as beneficial TA feature over some TLI methods. Also, due to the teacher absences, one third-grade TA class received only 11 instead of 12 intervention sessions.

Intervention sessions were conducted by the classroom teachers, which did not allow me an opportunity to monitor the length of sessions. Teachers of TA groups reported that all intervention sessions were kept within a few minutes of the 20-minute time frame. Both third-grade and one fourth-grade TLI teacher admitted that their comparison sessions typically extended at least 10 minutes over the appointed session time. These extended sessions provided

TLI students with more overall minutes of multiplication practice. Even with this limitation, TA students' level of mastery improved at least as well to better than TLI students

MAS Research Instrument

In order too keep the MAS at a feasible length for elementary age students; questions that were grouped by scale factors included only 1-5 questions. Scales that had less then three questions were not adequate for reliability testing and were analyzed only by individual questions. A slightly longer MAS including at least 3 questions per scale factor, would have been beneficial in allowing for analysis by all scales in addition to individually by question. Also, students after responding to all of the MAS Likert-type questions were less willing to spend ample time providing useful data in open-ended response. Many students provided no written response at all, or gave one word or ambiguous answers. Having the open-ended questions at the beginning of the survey may have allowed for richer and more complete responses from students.

Future Research

Findings from this study provided statistical evidence that learning in TA's instructional environment had a positive impact on student's multiplication mastery and self-efficacy for this particular population of students; however, while this study did involve four classrooms of students, it still involved a relatively small statistical population. A study that involves a larger and more diverse subject pool should be considered. This would provide data that is less likely to be affected by limitations such as student absences.

Furthermore, a subsequent study (whether through TA or another program) that allows subjects more adequate CAI intervention time should be considered. Longer study sessions would provide slower and less knowledgeable learners the complete learning experience intended by the program designer. In addition, it would have provided a more accurate comparison with TLI subjects that were taught all the facts on the multiplication post-test. A comparative study that explores the length of time the average student takes to successfully master multiplication facts using CAI compared to other more traditional methods could be useful information for elementary educators limited by insufficient instructional time.

This study did not involve teacher or parent views regarding TA's impact on student abilities and self-efficacy. A study that incorporates data from these two populations may provide valuable and new insights. In addition, this study did not consider learning abilities among students. Comparisons on TA's self-efficacy and mastery effects between high and low achieving students may also provide valuable information for educators who may be looking for methods effectively benefiting both of these population.

This study did not consider any differences TA's learning environment might have on performance among students with different learning abilities. During the study it was observed, however, that both low and high achieving students seemed to enjoy playing TA equally. In fact, one autistic student at the conclusion of the study asked his teacher if he could come in during every recess and play TA. The teacher agreed if he could find a friend who would also come in and play during recess, and if the student had good behavior during class time. This autistic student's classroom behavior improved and this student was always able to find another student willing to come and play TA during recess. A study comparing educational video game play's impact on students multiplication performance and self-efficacy between learning disabled (emotional or mental) students with low and average to high achieving abilities should be considered in further research studies.

This study found TA game play to be at least as effective as TLI methods in improving students' speed and accuracy when solving basic multiplication facts. Multiplication mastery combined with conceptual understanding of multiplication is both needed in order to accurately and efficiently solve more complex problems involving multiplication. Future research which compares TA only with TA plus TLI methods and TLI only methods in solving more complex problems involving multiplication should be considered to determine TA's affect on student's overall multiplication fluency in regards to both mastery and conceptual understanding.

Finally, as CAI can be costly and require technology not available to all schools or students, it is recommended that a study be conducted to explore non-CAI learning environments that closely align to TA's motivational, self-paced, self-evaluative, less stressful environment. Moreover, research that compares TA to other multiplication computer programs, with some similar yet different features, should also be considered. This could provide additional theoretical insights into CAI features that have a greater impact on student multiplication mastery and self-efficacy.

Conclusion

This study found TA to significantly help some elementary age students improve their level of multiplication mastery and self-efficacy. Comparison of multiplication pre- and post-test scores within TA third- and fourth-grade study groups found TA students to have significantly increased their level of multiplication mastery after having 12 20-minute sessions of TA game play. Analysis also found on average that TA fourth-grade students' self-efficacy scores significantly improved after intervention. TA third-grade students felt learning multiplication facts to be significantly less dull and boring and TA fourth-graders reported feeling less anxious when learning multiplication facts after intervention.

Analysis between TA and TLI multiplication pre- and post-tests found TA to be as effective as TLI methods between third-grade study groups in improving students' multiplication mastery. Comparison of TA and TLI fourth-grade study groups found TA students to significantly ($p < .01$) answer more multiplication facts correctly then TLI students after intervention, where no initial differences in mastery existed. Analysis of the MAS self-efficacy scale items found no significant differences between TA and TLI third- and fourth-graders pre-survey response scores and fourth-graders TA and TLI self-efficacy post-survey scores. Third-grade TLI over TA students had significantly higher ($p < .05$) self-efficacy scale post-survey mean response scores and social persuasion question scores. This may be due to TA students having less social support and encouragement from teachers during game play then TLI students had during study sessions. Social persuasion is a factor that according to Bandura (1997) can significantly influence self-efficacy beliefs. Comparison of individual post-MAS Likert-type items between study groups, however, found fourth-grade TA students significantly ($p < .05$) less nervous and uneasy when learning multiplication facts then fourth-grade TLI students. Post-MAS scores also found fourth-grade TA over TLI students feeling more confident that the multiplication activities they were doing were increasing their multiplication mastery.

Overall TA seemed to have the greatest significant impact on student's multiplication mastery and self-efficacy with fourth-grade over third-grade students. This may be due to the fact that fourth-grade students had been taught all of their facts the previous year and TA provided an engaging, self-paced, self-evaluative environment helping students improve recall on the facts they had not mastered the previous year. Third-grade students having very little prior multiplication knowledge were learning most of the facts for the first time through TA game play and the 12 20-minute sessions may not have been adequate to both learn and master basic multiplication facts.

Not all CAI software programs may have the same positive results that TA's video game play learning environment produced. TA's self-paced features allowed for individual practice and students were not found reviewing facts they already new with the whole class, as was observed in some TLI sessions. TA students were also given immediate feedback and did not have to wait for teacher feedback to know if his or her answer was correct. One student when asked if TA helped him learn his multiplication facts stated, "I like math now because I know more now. I can learn as much as I want and I do not have to wait for teacher, and you know right away if you got it right." TA also provided a fun, motivating environment where students remained engaged in learning. One student, when asked why he played TA said, "I like it because it is fun and helps me learn my times tables." Another student reported, "I like playing Timez Attack because it makes me happy, and it keeps my brain concentrating better."

Educators and parents looking to help students improve their multiplication mastery and self-efficacy should consider using CAI software programs, which include the same engaging, self-evaluative, self-paced features included in TA's learning environment.

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APPENDIX A: MULTIPLICATION TEST

Multiplication Facts 2-10s 100-item Two-minute Timed Test

2x7=	3x6=	2x3=	6x2=	8x2=
3x3=	9x2=	8x6=	6x3=	4x6=
2x6=	4x3=	5x3=	4x5=	9x6=
3x7=	8x7=	3x6=	4x8=	4x7=
3x6=	10x8=	4x7=	7x7=	5x5=
3x8=	6x6=	8x3=	4x8=	2x8=
2x6=	4x7=	3x3=	8x6=	8x7=
4x4=	9x7=	8x7=	7x7=	6x8=
7x7=	2x7=	10x8=	7x6=	9x7=
2x7=	10x6=	3x8=	6x6=	4x8=
7x6=	4x6=	5x8=	3x7=	7x8=
4x8=	5x7=	8x8=	9x6=	4x8=
7x8=	2x8=	7x4=	6x6=	9x8=
3x6=	9x2=	7x7=	4x8=	5x7=
8x7=	6x5=	6x7=	9x8=	9x8=
9x9=	2x8=	3x3=	8x8=	5x6=
5x6=	8x6=	5x8=	10x6=	2x2=
10x10=	6x7=	4x6=	3x6=	10x6=
10x7=	5x6=	5x4=	4x2=	3x5=
2x7=	3x8=	8x8=	4x6=	4x7=

APPENDIX B: Pre- and Post-MAS

Multiplication Attitudes Survey
Directions for questions 1-21: Read each sentence. Decide which answer best describes your feelings about the sentence.

Circle "FALSE" if you think what it says is ALL FALSE.
Circle "false" if you think what it says is mostly false.
Circle the "**?**" if you don't know or are not sure.
Circle "true" if you think what it says is mostly true
Circle "**TRUE**" if you think what it says is ALL TRUE.

1. I am sure I can master the multiplication facts taught to me in class this year.	**FALSE**	false	?	true	**TRUE**
2. I am sure I can figure out even the hardest math problems that involve using multiplication math facts.	**FALSE**	false	?	true	**TRUE**
3. Even if new multiplication math facts I am taught seem harder than others, I can learn them.	**FALSE**	false	?	true	**TRUE**
4. I can master even the hardest multiplication math facts if I try.	**FALSE**	false	?	true	**TRUE**
5. I can master all of the multiplication facts if I don't give up.	**FALSE**	false	?	true	**TRUE**
6. Learning new multiplication math facts does not scare me at all.	**FALSE**	false	?	true	**TRUE**
7. Learning multiplication math facts makes me feel uneasy and nervous.	**FALSE**	false	?	true	**TRUE**
8. My mind goes blank and I am unable to think clearly when solving problems that involve using multiplication math facts.	**FALSE**	false	?	true	**TRUE**
9. It makes me scared to even think about having to learn multiplication math facts.	**FALSE**	false	?	true	**TRUE**
10. I try hard at mastering new multiplication facts that I am taught.	**FALSE**	false	?	true	**TRUE**
11. When I do activities to help me master my multiplication facts I work very hard.	**FALSE**	false	?	true	**TRUE**

12. I do as little work as possible when it comes to mastering my multiplication facts.	**FALSE**	false	?	true	**TRUE**
13. I keep working on learning new math facts until I have mastered them.	**FALSE**	false	?	true	**TRUE**
14. Working on mastering multiplication math facts is dull boring.	**FALSE**	false	?	true	**TRUE**
15. I like to work on learning new multiplication facts.	**FALSE**	false	?	true	**TRUE**
16. I like doing activities that help me master my multiplication facts.	**FALSE**	false	?	true	**TRUE**
17. My teacher makes me feel that I can learn all of my multiplication facts.	**FALSE**	false	?	true	**TRUE**
18. My teacher encourages me to practice the multiplication facts I do not yet know very well.	**FALSE**	false	?	true	**TRUE**
19. My teacher encourages me to learn all of my multiplication facts.	**FALSE**	false	?	true	**TRUE**
20. The multiplication activities I do have helped me master almost all the multiplication facts I have been taught in school this year.	**FALSE**	false	?	true	**TRUE**
21. In the past I have had success mastering my multiplication tables.	**FALSE**	false	?	true	**TRUE**
22. Most students in my class are able to master the multiplication math facts they have been taught.	**FALSE**	false	?	true	**TRUE**
23. How I have been learning my multiplication facts at school makes me feel…					

24. I enjoy learning my multiplication math facts when… (put your answer in the box below)
25. Learning my multiplication facts is easy for me when…(put your answer in the box below)
26. Learning my multiplication math facts is hard when… (put your answer in the box below)
27. When I see other kids do well at learning their multiplication facts it makes me feel …because…(put your answer in the box below)

APPENDIX C: OBSERVATION and INTERVIEWING PROTOCOL

Self-Efficacy Category	Sub-Category	Observation	Interviewing Questions
Physiological and emotional States (PES)	1. Enjoyment 2. Frustration 3. Anxiety 4. Apathy 5. Engaged/ motivated 7. Other	What emotional responses do the students exhibit while participating in the task? (With task refereeing to either teacher-led-instructional methods or TA gameplay)	1. How does learning your multiplication facts using this task make you feel? 2. You seem to be (enjoying, having fun learning with, anxious about etc.) this task. Why?
Vicarious experience (VE)	1. Positive 2. Negative	Students talk about or notice how other students are succeeding at learning their multiplication facts through doing the task.	1. How would it make you feel to know other students are better able to master their multiplication facts using this task then they were before using it? Why would it make you feel this way? 2. (TA only) What do other students say about their multiplication mastery performance since they have been using TA? Why do you think Ta is helping or not helping them (or doing whatever it is he/she says students are saying)?
Social Persuasions (SP)	1. Positive 2. Negative	Encouragement by teachers/others concerning student's correctness or improvement of multiplication mastery.	1. What things does your teacher do to try and encourage you to learn your math facts? 2. What do others (i.e. teachers, peers, parents) say about how well you are doing at learning your multiplication facts? 3. Has what other thought about your multiplication master performance changed since you have been using this task? Why do you think it has or has not?
Performance Experience (PE)	1. Positive 2. Negative	Students refer to task having helped them improve their multiplication mastery.	1. How do you think this task has affected your multiplication mastery? (TA only) 2. Some kids might play TA because they think it is fun. Do you feel playing TA is actually helping you master your multiplication facts? Why? 3. Do you think you would have better success with learning your facts if your teacher was helping you instead? Why?

APPENDIX D: FIELD NOTES RECORDING SHEET

Date: Session: Class:

Description of Instructional Method if not TA:

Time of Episode: _____________

Episode 1: student comment, action, other, response to question ______ (i.e. PES 1)

Description of Episode:

____

____

____

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____________ Preliminary Code _____ Thoughts or Questions:

Time of Episode: _____________

Episode 2: student comment, action, other, response to question ______ (i.e. PES 1)

Description of Episode:

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____________ Preliminary Code _____ Thoughts or Questions:

Time of Episode: _____________

Episode 3: student comment, action, other, response to question ______ (i.e. PES 1)

Description of Episode:

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____________ Preliminary Code _____ Thoughts or Questions:

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APPENDIX E: CODING FOR MAS OPEN-ENDED QUESTIONS

Codes for Question 23

Code	Sub-code	Example
Positive		"Very good and smart" "Happy" "Awesome" "That I can do it." "Like I can do anything that involves math."
Positive	Timez Attack	"I really feel good when I am playing Timez Attack." "I like this because Timez Attack is a fun challenging game for me." "Happy and not as scared now with Timez Attack." "Happy especially with Timez Attack."
Negative		"I don't like it" "Sad" "Not good and bored" "Kind of frustrating."
Negative	Anxious	"Weird and nervous "Kinda scared"
Ambiguous		Unsure, no response or could not make sense of their response

Codes for Question 27

Code	Sub-code	Example
Positive		"Good, I like to see people succeed." "Happy" "Happy they are learning."
Encouraged		"Good because if they are learning I know I can learn." "Encouraged" "Like I want to do better."
Negative		"Jealous" "Sad because they know it and I don't." "Left out." "Like I am bad at it, because they have a way better score."
Ambiguous		Unsure, no response or could not make sense of their response

Codes for Question 24, 25 and 26

Code	Sub-code	Example
Location		"I am in school" "I am at home" "I am at math class" "It is quiet just me on my bed."
Negative (Also could be positive for question 26)		"Never" " It is hard" "I can not learn them"
Positive (Also could be negative for questions 26)		"Always" "Whenever" "Ever I can" "They are easy"
Activity		"I play games." "Play games with multiplication." "Playing mathematical battles" "On the computer." "I am getting help."
Activity	Timez Attack	"I get to play Timez Attack." "I am playing Timez Attack."
Frame of Mind		"I am happy." "I am relaxed." "I feel like trying" "I pay attention" "I do not listen"
Time Period		"After lunch." "In the morning." "After school."
Ambiguous		Unsure, no response or could not make sense of their response