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Improving multiplication fact recall; Interventions that lead to proficiency with mathematical facts

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IMPROVING MULTIPLICATION FACT RECALL:

INTERVENTIONS THAT LEAD TO PROFICIENCY WITH MATHEMATICAL FACTS

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Abstract

This three-week study focuses on basic multiplication fact recall. Twenty-six fourth grade students from a public school took a baseline test to quantify their multiplication fact recall. These 26 students then received 11 ten-minute practice sessions targeted to improve automaticity with multiplication facts. Each student was placed in a randomly assigned group for 11 practice sessions. Each of the four groups were assigned different modes of practice including: 1) flash cards; 2) paper and pencil practice; 3) website – XtraMath.org; 4) website – Multiplication.com. The results show that all students experienced growth from the baseline test to the post-test, with the XtraMath group showing an overall larger growth in comparison to the other groups. Results of the study also report differing levels of student motivation associated with each mode of practice: the computer-based centers retained a higher level of motivation while the other groups' motivations diminished over time.

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INTRODUCTION

As students are expected to master more developmentally challenging mathematical processes as they progress educationally, the question of how to ensure proficiency among students becomes a cloudy topic. Research continuously shows that performance increases with deliberate, focused, and leveled practice as well as high-quality instruction (e.g., Coyle, 2009). However, students don't always learn at the level of their peers, leaving a gap in fact recall knowledge. Teachers need to recognize this gap and understand that all students must achieve proficiency with fact recall. Doing so not only helps students avoid mathematics anxiety but also encourages seeking mathematical applications outside of school (e.g., Lyons & Beilock, 2012).

As educators recognize the necessity for quality mathematical instruction, different systems must be in place for all students in order to achieve mastery (e.g., Van de Walle, 2004). Strategies such as the Commutative Property and Doubles Plus Doubles sometimes carry different names; however, commonalities between productive methods are quite prevalent (i.e., Wong & Evans, 2007; Wallace & Gurganus, 2005).

The opportunities for different forms of appropriate practice are also necessary. Looking at the progression of difficulty with particular facts can help an educator scaffold direct instruction lessons (Silbert et al., 1990). Being attuned to students' different motivations (i.e., using technology, setting goals) can also lead to a higher desire to continue practicing toward mastery (Covington, 1992).

Cognitively speaking, practitioners also need to recognize the connection between our human brains' memory systems (such as working, short-term, and long-term memory) and the role fact recall plays in focusing more attention on meaning and deeper applications (e.g.

Willingham, 2009). By instantly recalling mathematical facts, students can focus their attention to solving problems requiring more advanced skill.

Statement of the Problem

Multiplication fact fluency is an essential ability for students to develop as they progress throughout elementary school, specifically with estimation skills and operations with larger numbers (Everyday Mathematics, 2002). While some students are proficient with fact recall, others often struggle throughout high school. In order to adequately prepare students for more difficult mathematical concepts during middle and high school, every student must become proficient with mathematical fact recall (Wallace & Gurganus, 2005).

This study was conducted to explicitly address the following two questions:

- Fact Recall: To what degree will the mode of practice impact student achievement on recall of multiplication facts?
- Motivation: To what degree will the mode of practice impact student motivation related to recall of multiplication facts?

Terms

The following terms are used within this paper. To avoid possible ambiguity with these terms, definitions have been included.

1. Multiplication: The abbreviated process of adding an integer to itself a specified number of times. For example, 3 x 4 is the same as adding 3 + 3 + 3 + 3. This process can be shown several ways, including arrays, number lines, and equations. (Definition taken from the Merriam-Webster Online dictionary: http://www.merriam-webster.com/dictionary/multiplication)

2. Factors: The numbers that are multiplied with each other. For example, in the equation 3 x 4 = 12, the integers '3' and '4' are the factors.
3. Product: The answer to a multiplication problem. For example, in the equation 3 x 4 = 12, the answer of '12' is called the product.
4. Multiplication Table: A reference used by students to show the products of two factors. Multiplication tables commonly show factors between 0 and 12, but these tables can also be modified to fit the range needed per student, teacher, or classroom.
5. Fact Fluency: Synonymous for "automatic recall", mathematical fact fluency is the ability to accurately and quickly recall basic addition, subtraction, multiplication, and division facts (Burns, 2005; McCallum, Skinner, & Turner, 2006; Poncy, Skinner, & Jaspers, 2006). Solving a particular fact within two seconds is considered the appropriate level for automaticity with facts (Frawley, 2012). (Definition taken from the Innovations and Perspectives at Virginia Commonwealth University website: http://www.ttacnews.vcu.edu/2012/02/developing-math-fact-fluency.)
6. Drill-and-Kill: A term associated with a negative connotation for rote memorization of mathematical facts. Mathematically speaking, drill-and-kill refers to drilling students with mathematical facts to the effect that it hinders motivation to learn.
7. Working Memory: A type of memory that allows people to keep several pieces of information active while trying to do something with them. For example, when solving a problem such as 44 x 7, keeping the numbers 40 and 4 broken apart in our minds as they are both multiplied by seven is using our working memory. (Definition taken from GemmLearning's website: http://www.gemmlearning.com/working_memory_definition.php.)

8. Long-Term Memory: A type of memory that allows people to retrieve items from a vast pool of memories, even if that specific memory hasn't been retrieved over an extended period of time. (Definition created from an article by the Department of Psychology from a Florida State University website: http://comminfo.rutgers.edu/~kantor/t/MLIS/551/public_dump/morris_a_11.html).
9. Zone of Proximal Development: "The distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (Definition quoted from Lev Vygotsky's *Mind in Society: Development of Higher Psychological Processes*).
10. Mathematics anxiety**:** Negative feelings associated to numbers, mathematical concepts, and mathematical problem solving. (Definition created from Ahmed et al., 2012).

Significance of Review

Learning basic mathematical facts is a foundational necessity required to learn higher mathematical strategies with efficiency (Mauro, LeFevre, & Morris, 2003; Singer & Greer, 2005; Everyday Mathematics, 2002). Starting in kindergarten with recognizing numbers, counting, and solving basic addition and subtraction facts and continuing past the fifth grade with multiplication and division, students practice these facts in a variety of methods. Teachers offer flash cards, timed tests, website games, and computation games to help build fact fluency. Often parents drill their kids with flash cards in addition to the regular school routine (Van de Walle, 2004).

The importance of being fluent with mathematical facts becomes more apparent in the upper elementary grades. As students learn a variety of topics such as multi-digit division, equivalent fractions, multiplying with decimals, and calculating perimeter and area (all requiring basic fact knowledge), those with stronger factual knowledge are able to use less working memory on factual recall and more of their working memory on solving the problem accurately (Willingham, 2009; McLean & Hitch, 1999).

REVIEW OF LITERATURE

In order to build the context for understanding which instructional methods will be more effective in helping students to recall multiplication facts and to be motivated to recall these facts, this study explores three associated areas of literature: the human memory, teaching strategies, and mathematics anxiety. With these three main concepts guiding the three-week intervention, implications for future action will be discussed.

Mathematical Fact Recall in Relation to Different Memory Systems

“Memory is the residue of thought” (Willingham, 2009, p. 41). In order to remember classroom rules, how to tie your shoes, or where your house is located, in one context or another, you must actively think about these topics in order to remember them.

The mathematical strategies later in this paper include teacher-led instruction and computer-based practice. In each scenario, students are thinking about, learning, and remembering mathematical facts. However, research about different types of memory provides teachers with different implications for students’ thought processes while learning multiplication facts.

The role of working memory. Working memory has been identified as the location in the mind where all active thinking occurs. This type of memory has a limited about of space, so that space must be used wisely (Willingham, 2009). Working memory is also linked to students’ mathematical performances (McLean & Hitch, 1999); proficient students use instant factual recall to solve problems whereas struggling students often use much slower strategies (i.e., skip counting, finger counting, looking on a multiplication table). Furthermore, research has also shown that students' performance with factual recall can be used to accurately predict word problem accuracies (Swanson & Sachse-Lee, 2001).

While researchers agree that the size of working memory varies on an individual basis, there are two main ways to use less working memory space: obtain factual knowledge and make the desired process more efficient (Willingham, 2009). These methods work in conjunction with one another, as becoming efficient with facts is the basis for instant factual knowledge retrieval. In support of these discoveries, researchers have also found that a person's working memory capacity and efficient use of working memory has relation to more advanced mathematical problem solving tasks such as carrying numbers when multiplying using the traditionally taught method (Seitz & Schumann-Hengsteler, 2000). As students become proficient with multiplication facts, working can be spent elsewhere, allowing numbers to be manipulated accordingly.

Remembering and long-term memory. Long-term memory is referred to as "memory from experiences that occurred at a point in time prior to the immediate past" (Gathercole & Alloway, 2009, p. 113). When students have a solid understanding of multiplication facts, those students have the ability to instantly recall those facts from long-term memory. Thus, little to no working memory is spent trying to recall a factual answer (Willingham, 2009). When solving a word problem, for example, studies show that student with instant recall can focus more on the steps to solving a complex answer rather than having to stop and think about the product to a basic fact (e.g., Seitz & Schumann-Hengsteler, 2000).

When long-term memory is used for recalling particular steps required to solve an algorithm, working memory space becomes available. As Gathercole & Alloway (2009) explain, “[Material] stored in long-term memory can boost our immediate memory performance by decreasing reliance on the very limited capacity of working memory” (Gathercole & Alloway, 2009, p. 16). In addition, students having proficient recall of multiplication facts and knowing the steps in solving an algorithm tend to experience less math anxiety when solving a complex mathematical task (Imbo & Vandierendonck, 2007).

The unreliability of short-term memory. An understanding of working memory and long-term memory must be separated from an understanding of short term memory. Potter (2012) explains that this type of memory is mostly unconscious, and little reflective understanding occurs. She also states that when momentary information is not tied to a person’s schema or related to previously understood concepts, that momentary information is quickly forgotten (Potter, 2012).

Willingham (2009), as reported earlier in this paper, discovered that one must actively think about a concept if that concept is expected to be remembered (Willingham, 2009). This directly connects with Potter’s research. If a teacher tells the students that 7 x 6 = 42 and then asks what 7 x 6 is, students are most likely recalling 42 from their short term memory. No deep cognitive thinking actually occurs, and that fact will most likely be forgotten.

Mathematical Strategies to Aid Proficient Recall

A variety of strategies and methods exist for teaching students multiplication facts. These differences include the medium used (i.e., computer-assisted learning, written facts, verbal recall), outcomes for understanding (i.e., game-based learning, timed drills, patterns and associations), and the amount of repeated exposures. By having an understanding of these different strategies, facilitators can help students become proficient with their factual recall.

Teacher-led instructional strategies. From as early as preschool, children are taught about numbers, counting, patterns, and mathematical associations. Specific to basic facts, students begin by learning about addition and subtraction, eventually working their way up to mastering multiplication and division. As they progress throughout their elementary years, students are exposed to many different instructional strategies (i.e., Baroody, A.J., 1999; Lemaire, P., Barrett, S.E., Fayol, M., & Abdi, H., 1994; Steel, S., & Funnell, E., 2001). By looking at the large body of research involving these instructional strategies, teachers have the ability to decipher what their children need to achieve proficiency.

A progression of multiples. Several researchers recommend introducing multiplication with a particular sequential order of different multiples in mind. Van de Walle (2004) sequences multiples of 2, 5, 0, 1, and 9 first (Van de Walle, 2004). He states that by teaching these generally easier facts first, 75% of all basic multiplication facts will be learned. He then continues to describe the other 25% as helping facts, which can be learned by associating unknown facts with the already known facts.

Silbert, J., Carnine, D., & Stein, M. (1990) suggest a progression of facts very similar to Van de Walle. Wong & Evans (2007) used the research by Silbert, Carnine, & Stein to conduct a study introducing the advancement of multiples in a daily format. For each session, particular multiples were practiced; during the follow session, the easiest multiple of the previous set was replaced by a new and more difficult multiple. For example, during the first session, students would learn and practice the multiples of 1, 2, 5, and 9. The next day, students would no longer practice multiples of 1; rather, they would be introduced to multiples of 4 (the next multiple in the developmental progression). This progression continued until strategies for each of the basic facts were taught and practiced.

Several mathematics curricula also teach with a progression similar to Van de Walle and Silbert, Carnine, & Stein. First, Houghton-Mifflin's *Math Expressions* details lessons which introduce multiples of 5, 2, 10, 9, followed by 3 and 4, then 1 and 0, completed with 6, 7, and 8. Next, the *Everyday Mathematics* curriculum exposes fourth graders to 0, 1, 2, and 10 first, followed by 6, 7, and 8. Although these sequences aren't exact matches, particular commonalities exist (i.e., multiplying by 2, 5, and 10 to begin; ending with 6, 7, and 8). These two curricula also provide a solid understanding of the importance of teaching multiplication facts with a progression of difficulty in mind.

Associated multiplication facts. Another instructional strategy used to teach multiplication facts is the association of facts. Cognitive scientists emphasize the importance of the ability to draw upon foundational background knowledge. Willingham (2009) explains that experts think in terms of abstract representations: when solving a problem, those experts draw upon background knowledge to solve new and similar problems (Willingham, 2009). As educators continue to teach students strategies to become experts at multiplication fact recall, connecting known facts to unknown facts is essential in establishing proficiency.

One of the most essential properties of multiplication is the commutative property. After teaching this strategy (sometimes informally called Turn-Around Facts), students can find, for example, that finding the product of 6 x 7 is the exact same as 7 x 6. By discovering the presence of the commutative property, learning all basic facts is actually half the task it originally appears to be (*Everyday Mathematics*, 2002; Van de Walle, 2004).

A second property of multiplication is the identity property. Using this strategy, students can quickly realize that any number multiplied one time assumes its identity. That is, anything times one is that original number. By teaching this strategy, students can not only multiply some single-digit multiplication facts, but they also have the ability to learn extended facts (i.e., 1 x 5 = 5, 1 x 50 = 50, and 1 x 500 = 500) (Silbert et al., 1980). This will help students prepare for multiplying multi-digit numbers, especially when using a strategy such as "Partial Products" (Everyday Mathematics, 2002).

Another strategy used to help learn and understand multiplication facts is looking for associations between known facts and unknown facts. Van de Walle (2004) summarizes these associations with four approaches. The first, Double and Double Again, refers to multiplying with fours. If a student knows 6 x 2, finding 6 x 4 is as easy as doubling six and then doubling 12. Next, Double and Add One More Set refers to multiplying with threes. If a student knows 7 x 2, finding 7 x 3 is as easy as adding one more set of 7 to 14. His third approach is referred to Half Then Double. If a student is trying to solve a problem such as 6 x 8, by finding 3 x 8 and then doubling 24, the student will figure out the correct answer. The last approach, Add One More Set, refers to problems such as 7 x 6. If a student already knows 7 x 5 = 35, finding 7 x 6 is as easy as adding 7 more to 35. Using strategies such as "double and double again" will help students learn the other 25% of multiplication facts (Van de Walle, 2004).

Timed assessments. Research has shown that proficient multiplication recall can be developed in an environment of high frequency, repetition, and leveled practice (Baroody, 1999; Steel & Funnell, 2001). Using timed assessments can be effective when used in this type of environment.

Caron (2007) describes a timed assessment where students were given a set of facts with answers to the questions at the top. Students tried to answer as many as possible in the given amount of time. Since the answers were immediately available, mathematics anxiety was avoided – students started to think of this practice as a game. Ultimately, he emphasizes that repeated practice in a timed setting is all that is needed (Caron, 2007).

Similar to Caron, Wong & Evans (2007) created an intervention based on deliberate practice. Students were given ten minutes to practice facts each day for eleven days. During the first eight days, students were given a multiplication table and encouraged to use it if needed. For days nine through eleven, students practiced multiples previously covered but without a multiplication table, hoping to establish facts in long-term memory (Wittman et al., 1988).

The concept of high amounts of repetition combined with leveled practice fit the research outside of education as well. Studies by Coyle (2009), Rohrer & Pashley (2007), and Willingham (2009) all recommend focused, extended, and deliberate practice in any area one wishes to improve. Doing so will lead to the mastery desired.

Committing necessary time for students to practice. In the fourth grade curriculum of *Everyday Mathematics* (2002), only three lessons for explicit multiplication fact practice exist. The authors recommend administering a 50-Facts Test approximately every three weeks (Everyday Mathematics, 2002), but the rest of elicit fact practice comes from solving different types of problems and playing a variety of games (i.e., multiplying or dividing multi-digit numbers, playing Name That Number). Teachers must look at student performance to see if this is sufficient practice to achieve automaticity.

Regardless of the curriculum, deliberate practice opportunities must exist for students to be successful. In regard to deliberate practice, Willingham (2009) states, "Two reasons to practice – to gain competence and to improve – are self-evident and probably are not very controversial. Less obvious are the reasons to practice skills when it appears you have mastered something and it's not obvious that practice is making you any better. Odd as it may seem, that sort of practice is essential to schooling. It yields three important benefits: it reinforces the basic skills that are required for the learning of more advanced skills, it protects against forgetting, and it improves transfer" (Willingham, 2009, p. 82).

Researcher Ericsson (1995) looks to advance the usage of deliberate practice, remarking that this particular type of practice must push a student past his/her current ability level yet still provide opportunities for failure as well as analysis of those failures. Being a problem solver and receiving appropriate feedback will continue to advance a student's abilities (Ericsson, 1995).

Computer-assisted learning strategies. With the implementation of Common Core in forty-seven of the fifty United States, schools across the country have been addressing the issue of "Technology Literacy" (Iowa Department of Education, 2012). Within "Technology Literacy", students are expected to use technological tools to answer questions, access information, and select and use technology to accomplish positive tasks (Iowa Department of Education, 2012). With this Common Core in place, what part can technology play in assisting students with learning basic multiplication facts?

The importance of immediate feedback. To begin, a wide body of research shows that accurate practice increases fluent factual recall (Skinner, 1998; 2010; Skinner, Belfiore, Macc, Williams, & Johns, 1997; Skinner, Bamberg, Smith, & Powell, 1993; Skinner & Shapiro, 1989). To assist with accurate practice, computers have the ability to provide immediate feedback. When using appropriate programs, students can receive immediate feedback for both correct and incorrect answers. Responding in such high rates with immediate feedback, students will cease to answer questions incorrectly (Parkhurst, Skinner, Yaw, Poncy, Adcock, & Luna, 2010).

Appropriately leveled practice. Another benefit of some technological programs is the computer program's ability to generate problems matching each student's Zone of Proximal Development (Vygotsky, 1978). For example, the website *XtraMath*, dedicated to mathematical fact fluency, provides practice by using "sophisticated methods to present students with the right problem at the right time to maximize the effectiveness of practice" (Xtramath.org, 2013). When students are challenged appropriately, mathematics anxiety can be avoided. Research has found that when students suffer from mathematics anxiety, an avoidance of mathematics and mathematical-related scenarios often occur (e.g., Lyons & Beilock, 2012). If this type of computer program is used to generate questions accurately, students have the opportunity to practice particular fact families when they are developmentally ready. John A. Van de Walle (2004) warns, "Premature drill introduces no new information and encourages no new connections. It is both a waste of time and a frustration to the child" (Van de Walle, 2004, p. 174). Using computer-based programs such as *XtraMath* help students practice facts within their Zone of Proximal Development. This not only allows students to experience high levels of success but also helps circumvent mathematics anxiety.

Fostering engagement and motivation. Moving into the 21st century, students are surrounded by many different forms of technology, both at home as well as at school. Both Cassidy (2003) and Jenkins (2002) discovered some evidence showing the use of computer games as having the ability to teach people more effectively than traditional teaching methods (Cassidy, 2003; Jenkins, 2002). Gaming websites focusing on appropriate fact practice can also lead to proficiency with factual recall (Vogel et al., 2006). For example, *Multiplication.com* offers gamers the opportunity to pick from a plethora of games, including single-player as well as multi-player games. Within each single-player game, students have the opportunity to choose particular multiples to practice as well as a range of multiples. This allows students to again challenge themselves at an individual and appropriate level (Multiplication.com, 2013). Additionally, others have documented that computer games provide motivation, high levels of engagement, and a positive interactive experience for the user (i.e., Kafai, 2001; Vogel, et al., 2006).

When looking for computer programs and websites that match the above criteria, research implies that practitioners should to focus on technology that can provide accurate and immediate feedback (e.g., Skinner, 2010), is motivational for the user (e.g., Kafai, 2001), and has the ability to adapt to match each student's instructional needs (e.g., Van de Walle, 2004).

The Challenges of Mathematics Anxiety

When teaching a skill that requires repetitive practice, such as multiplication facts, it is important to keep student, parent, and teacher attitudes in mind in order to help motivate students toward achieving proficiency. Failure to do so can lead to mathematics anxiety, causing students to avoid mathematically-related situations and career paths (Ashcraft, 2002).

What is mathematics anxiety?. While researchers agree that mathematics anxiety in students is important to consider, the exact relationship between self-concept and anxiety is often questioned. Bandura (1997) believes that causality starts with self-concept and moves toward anxiety (Bandura, 1997). Beck and Clark's research (1997) views anxiety as characterized by self-image. That is, when experiencing anxiety, an individual may judge one's capabilities with mathematics as lacking (Beck & Clark, 1997). Researchers Wu, Barth, Amin, Malcarne, & Menon (2012), however, found that the similar trait anxiety analyzed in Beck & Clark's research cannot be considered the primary cause of mathematics anxiety (Wu et al., 2012). A third perspective assumed self-concept and anxiety as working in a reciprocal way (Pekrun, 2006; Zeidner, 1998).

Having a growth mindset. Dweck (2010), a leading researcher on people's mindsets, divides students into two categories: those having a *fixed mindset* and those having a *growth mindset*. Students with a fixed mindset believe that the amount of intelligence one has is predetermined. This causes those particular students to try less, as it is more important to look smart. Some students, however, have a growth mindset. These students look for challenges to be scenarios in which they can learn and grow as a thinker (Dweck, 2010).

Several authors and researchers support this same point: all people have the ability to grow and adapt to challenges. Author Shenk (2010) explains that our brains and bodies are ready to experience plasticity (the ability to become better) (Shenk, 2010). Neuroscientists Johnson and Karmiloff-Smith (2010) describe our brain development not as a plan waiting to naturally occur, but rather as "an activity-dependent process at the molecular, cellular, and organismal" level (Shenk, 2010, p. 131). Finally, Meltzoff (2003) notes that even babies' ability to make alterations when challenges require them to do so is what makes our being special (Meltzoff, 2003).

Use goal setting to track growth. When students set goals, they are making a commitment to influence action (Latham & Locke, 2007; Locke, Shaw, Saari, & Latham, 1981). Setting goals and working toward a positive outcome can be so powerful that Davidson (1994) has described it as a form of happiness, called pregoal attainment positive affect (Davidson, 1994). When teachers help students set these types of goals, anxiety can be tapered.

As teachers set aside time for students to set goals, they should remind students to focus on their individual growth rather than compare oneself to the others in class (Bekdemir, 2010). Having students set individual goals and track individual growth can help alleviate anxiety caused from mathematics. Newman (2012) explains that setting goals "is one of the most important strategies and routines that can be put into place to fundamentally shape the practice of leadership in a school and more pointedly achieve results" (Newman, 2012, p. 13).

Parents and mathematics anxiety. Research has shown that family income level (Jordan, Kaplan, Olán, & Locuniak, 2006) and parental attitudes (Scarpello, 2007) toward mathematics can help determine children's levels of mathematics anxiety. By understanding these concepts, parents have the ability to positively influence their children's anxiety levels in different ways.

Influences from socio-economic status. Parents of all socio-economic statuses can drastically influence a child's attitudes, expectations, and educational experiences. Parental encouragement, especially from one's mother, has been found to drastically influence both students' attitudes and educational experiences. Parents have also been found to provide encouragement to their children toward a particular career path. As students encounter anxiety in any particular subject, the encouragement and support can lead to children focusing on challenging courses, widening the possibility of different career choices. However, a child's home environment has the potential to negatively affect one's attitude toward mathematics. Parents in a low socioeconomic setting often have limited mathematical knowledge and a negative attitude, which can be passed on to a child as well (Scarpello, 2007).

Mathematical achievement by gender. Parents and teachers must consider how they interact with their children, regardless of gender. The research of Jussim & Eccles (1990; 1992) has shown that many teachers are biased in regard to boys' and girls' learning achievement. They found that boys' success relies on talent while girls' success is due to hard work (Jussim & Eccles, 1990; Jussim & Eccles, 1992). These potentially false attitudes from both teachers and parents can be internalized by children, causing a loss of confidence, enjoyment, and achievement when learning mathematics (Geist, 2010).

Encouraging a growth mindset rather than a fixed mindset. In a group of studies by Yeager and Dweck (2012), two groups of students were praised in two different manners: one for having a growth mindset and the other for having a fixed mindset. This study showed that when students were praised for being smart, they often resisted future challenges and misconstrued their final scores from the trial. When students were praised for their abilities, they were more likely to continue solving future challenges (Yeager and Dweck, 2012). This research implies that praising natural giftedness often leads to students feeling incapable when facing an academic challenge. Rather, parental support must be focused on praising effort, determination, and persistence. Interacting with one's child in this manner can help reduce mathematics anxiety.

Teachers' response to mathematics anxiety. While achieving proficiency with mathematical facts plays an important part in the development of students' mathematical development (Everyday Mathematics, 2002), teachers must consider how pedagogical practices can potentially harm that development.

Create positive public experiences. A teacher's attitude plays a significant factor in mathematics anxiety. If an instructor portrays public negative attitudes toward students, including physical and verbal interactions, students can feel a loss of self-confidence and a doubtful outlook on making progress with mathematics (Bekdemir, 2010).

When considering teaching a lesson, instructors must also utilize effective instructional practices (Scarpello, 2007). This can be done in a variety of ways. First, during classroom instruction, teachers must make sure the students are provided with the support necessary to be successful within that lesson. Providing closely guided practice, offering opportunities to work with cooperative learning partners or groups, and supplementing interventions when students do fall behind are all ways to support student learning (Geist, 2010; Blazer, 2011). Additionally, Dweck (2010) suggests providing meaningful learning tasks to help students identify progress leading toward mastery. Outside of the classroom, she advises teachers that when assigning homework, students should be required to apply learned concepts to a new and deeper level of learning (Dweck, 2010).

Recognize one's own attitudes toward mathematics. Bekdemir's research (2010) with teacher candidates has shown that many of these teachers enter the profession with an already-present anxiety toward mathematics (Bekdemir, 2010). This can often lead to teachers unknowingly passing down anxiety to students, frequently by teaching in a similar matter with which they were originally taught. Teachers can cope with their own anxiety through professional development, using effective teaching methods, and providing encouragement during problem solving are three ways teachers can help decrease the amount of anxiety students experience throughout the school year (Scarpello, 2007).

Avoid using rote memorization. The instructional multiplication strategies outlined earlier mustn't be confused for the practice of rote memorization. Rote memorization refers to teaching facts individually, as students are being exposed to an answer repeatedly without being taught appropriate strategies, challenged with adequate progression, or having facts differentiated at an individual level. Often referred to as drill-and-kill, the practice of rote memorization can lead to students feeling anxiety toward mathematics (Geist, 2010).

Although a recent survey reported that 70 percent of teachers found rote memory to be a beneficial way to improve proficiency with mathematical facts, research suggests that this type of learning is largely ineffective (Caron, 2007; Woodward, 2006). Rather than relying on rote memorization of facts, terms, and concepts, teachers should encourage active learning within their classrooms. As students are provided with the opportunity to play content-related games, experience activities connected to the real world, and solve mathematical problems using different modalities, motivation will increase as anxiety lessens (Blazer, 2011; Sun & Pyzdrowski, 2009; Curtain-Phillips, 2001).

Understand learning as a process to be built upon. The authors of *Everyday Mathematics* state, "Mastery of the basic facts will give students surprising power in making quick estimates and operating with larger numbers" (*Everyday Mathematics*, 2002). In fourth grade alone, students are expected to multiply and divide multi-digit numbers, calculate area, perimeter, and volume, and convert fractions to decimals and percents. Having a solid understanding of multiplication is an essential skill that allows students to understand these concepts more easily.

In two separate studies which analyzed the relationship between multiplication and a move advanced mathematical skill, both studies found that multiplication played an intricate part in student success. Mauro, LeFevre, and Morris (2003) concluded that multiplication (not in conjunction with. but rather preceding division) is the basis for understanding both multiplication and division (Mauro, LeFevre, & Morris, 2003). Singer-Dudek and Greer (2005) concluded that basic understanding must occur before successfully learning more advanced mathematical concepts (Singer-Dudek & Greer, 2005).

Mabbott (2008) sums up the connection between mathematical facts and the rest of the mathematical gamut:

> The relations between conceptual knowledge [facts] and mathematical difficulties in multiplication have been ignored. Understanding multiplication involves knowledge of several related concepts that enable flexible problem solving. Consequently, we have asked children to solve problems based on a number of concepts that are important for multiplication" (p. 18).

In order for students to be successful with multiplication alone, one must understand place value, addition and subtraction facts, skip counting, number recognition, and sets/arrays. While multiplication is actually quite basic when comparing it to the highest levels of mathematics, parents and educations must have an immediate sense of urgency in teaching and supporting the learning of basic facts in order for students to have a better chance at success with more challenging topics such as calculus, quantum physics, and trigonometry.

METHODS

Overview of study. During my second year of teaching fourth grade, I began to grow curious about students' computational development. Within our curriculum, students were provided with an opportunity to track their growth throughout the school year. However, aside from the three suggested lessons to assess this growth, no guidelines were given. Thus, tracking a student's growth did not have much relevancy due to such little emphasis being placed on the scheduling of these checks. During those first and second years, I merely gave a 50-Facts Test whenever it seemed to fit, and when students under-performed, I didn't say much other than that they needed to try harder.

After tracking these scores my second and third years of teaching fourth grade, I started noticing a trend. Typically speaking, students who scored well on a basic timed multiplication test also performed well during everyday lessons as well as both formative and summative assessments. At the end of my third year, I simply stated to myself that all students in the coming year's class would achieve proficiency with fact recall, expecting this to also translate to student success in other mathematical areas.

At the start of the fourth year, I developed a basic formative assessment which I called a "6020". Students would have 60 seconds to answer 20 multiplication problems all pertaining to the same multiple (i.e., 6 x 1, 2 x 6, 9 x 6, 6 x 7). These would be given at the end of each math lesson, but students were never forced to take them. They had to ask to take a 6020 when they felt ready. If they weren't yet ready, they would spend those few minutes using different practice methods, including skip counting worksheets, flash cards, and online multiplication games.

Toward the end of that fourth year, having made proficient multiplication fact recall an important issue to our school day, our 50-Facts Test scores were significantly higher than the previous two years' scores. No other additions other than these 6020s were made to the curriculum, and since the class's first score was similar to the prior years' scores, so I concluded that the 6020s led to this success. However, I wasn't entirely pleased. While our class average was up to 95% (with the highest score from previous years being no higher than 84%), I recall having a conversation with my student teacher. I mentioned that while 95% was very high, it simply might not be possible for all students to answer all questions right all on the same day.

He looked at me very perturbed and said, “Do you really believe that?” That conversation stuck with me over the summer.

This year I decided to take the same path, only this time I would have more resources, more games, and more practice opportunities available to the class. These resources included worksheets to practice skip counting and fact association, manipulative tools such as Learning Wrap-Ups, iPad apps, and online math games that encouraged repeated practice. The 95% was admirable, but could the last five percent be accomplished? I decided to take the same route as I did the prior year, making adjustments accordingly. Unsurprisingly, this year’s class nearly mimicked last year’s class, but again, we remained stuck in the mid-90s. I began to ask myself if commonalities existed between the missing 5% of this year and the 5% of last year? I looked closer and realized that the last 5% was due a handful of students – the students that typically struggled to understand mathematics at the same level their classmates did. By using the concept of teacher research (Hubbard & Power, 2003), I focused on answering two main questions: how would different modes of practice impact both student achievement and student motivation. The creation of this intervention was my approach to helping the handful of kids that really needed it; however, I soon realized that everyone greatly benefitted from this intervention.

Study setting and participants. Harper Elementary School (HES) is located in one of largest cities in its state. The entire district is composed of over twenty elementary schools, six middle schools, and four high schools. HES has been the recipient of several awards, including the First in the Nation in Education award in 1987, the Elementary School Recognition Program for excellence in education in 1988, and Iowa Arts Council Grants in 1996, 1997, 1998, 2001, and 2003. Additionally, due to its high level of parental support through the volunteering program, HES was recently honored as a Parent Involvement School of excellence.

The school itself is comprised of grades kindergarten through fifth with each grade having three classroom sections. Each classroom is organized heterogeneously based on academic ability and behavior, is self-contained, and typically has between 19 and 28 students per section. In addition to the core curriculum, students are involved in art, music, physical education, library, counseling, and computer literacy throughout the entire school year.

HES's ethnicities include white (84.7%), Asian (3.5%), Hispanic (2.1%), and Black (9.7%). The student body is nearly split in terms of gender, having 54.4% of the population as female and the other 45.6% being male. The student to teacher ratio is 20.46 to 1. Having a class size of 26, the students of Room 127 includes an even split of boys and girls. The demographics of this classroom are similar to the school's averages. Additionally, two students have an Individual Education Plan in the area of reading, one student has been accelerated to fifth grade math, seven students have attended the math Program for Academic and Creative Talent (PACT) this year, and five have attended science PACT this year. Because this fourth grade classroom resembles a typical classroom consistent with the school's as well as the district's demographics, the sample size for this teacher research is purposeful.

While Room 127 is the second smallest of the classrooms at HES, the classroom space is utilized effectively. Located at the front-center of the room (with a larger carpet for students to sit during whole-class lessons), a Promethean interactive whiteboard is used daily. Students' desks are arranged in table groups of four or five, but students also often work with partners in different groups. The classroom also has marker boards available to students, two student computers, and a classroom library of over 2,000 books. Students also have two baskets on the countertops: one for mathematics materials and the other for their reading materials.

Description of the project. The purpose of this teacher research (Hubbard & Power, 2003) was to provide each of four different groups of students a method of practicing multiplication facts. Upon doing so, both the number of questions answered during each session as well as the level student of student motivation throughout the intervention would be analyzed. Furthermore, I wanted to see what the correlation would be between the number of problems solved, student motivation, and overall pre-, post-, and sustained-results tests would be.

To organize the study, students were first given a 50-Facts Pretest. During this pretest, students had one minute to successfully answer as many problems in a row as possible (written in blue marker). In the last two minutes, students could answer any remaining problems on the sheet before time ran out (written in green marker). Students also graphed their results of this pretest in their Data Folders, which houses a collection of different scores throughout the year. After finishing, I scored the tests and ranked the students based on their three minute score (using the one-minute score in case of a tie-breaker). When students were ranked, I placed each student, starting with the best score and working to the lowest score, in one of four groups. Thus, Group A had students 1, 5, 9, etc., Group B had students 2, 6, 10, etc., Group C had students 3, 7, 11, etc., and Group D had students 4, 8, 12, etc. Organizing the groups in this manner helped ensure that each practice method would have a mixture of high, middle, and low scoring students.

After organizing the students, I needed to prepare the materials. Group A needed no preparation since they were playing games from Multiplication.com. Group B needed flash cards, which were downloaded from Multiplication.com, printed on regular printer paper, and cut out and organized by each specific multiple. These flash cards were kept in manila envelopes labeled with each student’s name. I entered each student in Group C into XtraMath.org, selecting "Multiplication" as the practice method. These students were given an index card which included the classroom code and their individual log-in number. Finally, Group D needed four worksheets printed daily from WorksheetWorks.com (following the pacing guide previously listed). Last, I reserved the computer lab for ten minutes each day for the duration of the eleven sessions - four sessions during the first and second weeks and three sessions during the third week. During the third week, the final session was reserved for the 50-Facts Post Test, which was graphed in their Data Folders next to the each student's pretest results.

Throughout the intervention, I also made a record of observations. These observations were used to keep track of students that were absent, tracking members of Group A's preferred Multiplication.com games, remarks and conversations from students, and withdrawn behaviors from this intervention. I also kept a tally of each student's answered problems. To do this, Group A told me which game they each played and which level they each reached; Group B told me how many times they each went through their assigned flash cards; Group C's progress was reported through the teacher link on XtraMath.org; Group D's progress measured by scoring the hard copies of their paper-and-pencil assignments.

At the end of each week's sessions, I administered a student survey (see Appendix A) that focused on student motivation, expected outcomes, and preferred methods of practice. Students were initially reserved about speaking their feelings, but after the third week, several students were quite adamant about voicing their opinions.

Three weeks after the 50-Facts Post Test, upon receiving regular classroom instruction with no whole-class intervention, I administered the third 50-Facts sustained-results test. This was done to assess the retention of multiplication facts even after these intense sessions had concluded. This third assessment was graphed on the same bar graph as the 50-Fact pretest and

50-Facts posttest scores. Thus, students were able to see their growth throughout the course of this intervention. In addition to students having this data ready for their own independent analysis, I was able to collect the class's data to focus on my research questions.

Research questions. The research questions developed for this study targeted fact recall ("To what degree will the mode of practice impact student achievement on recall of multiplication facts?") and motivation ("To what degree will the mode of practice impact student motivation related to recall of multiplication facts?"). The research questions are asked in this format to allow me to draw a wider range of conclusions. For example, if I bluntly asked, "Which intervention was most beneficial?" I could provide an answer, but I wouldn't have much reason why. By asking the questions in this manner, I am able to look at both the beneficial and negative characteristic traits of each method.

Methods of data collection. While conducting this study, I focused on four different types of data collection, which are explained below. These were used to assess student progress, to give students a chance to voice their opinions, to record classroom interactions with students, and to understand successes among different groups.

Student test results. The main focus of this study was to improve students' proficiencies with multiplication fact recall. To begin, a baseline assessment needed to be administered to measure each student's current level of proficiency. This baseline test was a paper with 50 random basic multiplication facts listed in four columns. The students were given two different scores: the first score was based on the number of correct multiplication questions written correctly without skipping or errantly answering a fact in the first minute. The number of questions correctly and consecutively answered would be this first score. To distinguish the first minute questions answered, these facts were answered using a blue marker. The second score was the number of correct multiplication questions written correctly during the entire three minutes. Students were able to answer any questions on the fact test during this second and third minute, and their first minute score was included at the end to determine the total number of facts answered in three minutes. These answers were written using a green marker.

At the end of the three week intervention (the posttest) as well as three weeks after the intervention (the sustained results test), students were given another basic multiplication assessment using the exact same procedures.

Logging the number of problems answered. One of my examinations of the different modes of practice included the number of problems each group typically answered. Recording this number was a tedious, yet, essential component of this research. The group using XtraMath.org was easiest to track – when finished, the "Teacher" page reported exactly how many questions each student answered. The group using flash cards was asked to count how many times they went through their flash cards. Each session this group practiced 36 different flash cards; thus, after reporting how many times they went through them, I was able to multiply that given number by 36. The paper-and-pencil group turned in their work at the end of ten minutes. While it took a while to check this group's work, I was able to calculate the accurate amount. Lastly, the Multiplication.com group was a bit more challenging to record. Each student needed to report which game they played, how many levels were passed or how many times the game was played, and then I needed to calculate how many facts needed to be answered based on their reports. While collecting the number of problems answered was quite tedious, these numbers were essential to my research project.

Student surveys. At the end of each of the three weeks during this intervention, each student completed a survey that questioned their motivations, attitudes, and expected outcomes toward answering multiplication facts proficiently. The class was quite motivated at having the opportunity to provide their feedback. Several students also asked if this feedback would be used to change the intervention. Although the students' information wouldn't be used to alter this intervention, it could be used with future class's interventions similar to this one.

Teacher observation logs. The fourth method of data collection was keeping an observation log. This log was used for a few different reasons. First, I used the log to track when students were absent. Although there weren't any students who missed more than one day, if there had been, that particular student's scores would have been questionable due to the missed practice opportunities.

The second purpose of the observation log was to record student comments and teacher observations. On several occasions, a few students voiced their dislikes for their given methods of practice. While they briefly did express their dislikes, I simply reminded them that the time was short, and the personal best efforts were expected. Also, as I made my observations, I took note of which kids seemed the most engaged throughout the duration of each session as well as general attitudes among groups.

Methods of data analysis. The plan for data analysis evolved over the development of this intervention. Initially, this data analysis provided an understanding of student progress, but upon slight revision, a deeper level of analysis would be reached.

Initial data analysis. When constructing this intervention, I planned on collecting data on student performance on the 50-Facts pre-, post-, and sustained results tests. This seemed to easily explain my research question, "To what degree will the modes of practice impact student achievement on recall of multiplication facts?" Having given 50-Facts tests such as these for the past four years, I had several data points to compare. I planned on comparing both one-minute and three-minute scores over the past four years as well as looking at this year's class averages and standard deviations.

I also decided to provide the students with an opportunity to offer feedback at the end of each week of this intervention. This feedback would allow the students to reflect on how they felt about the intervention, highlighting their motivation levels, interests, and expected outcomes. By looking at how different groups' motivation levels, expected outcomes, and interests fluctuated throughout this intervention, I would also be able to make adjustments in the future based on these fluctuations. Ultimately, these student surveys provided a basic answer to my second research question, "To what degree will the mode of practice impact student motivation related to recall of multiplication facts?" In due course, these data sources led me to use the constant comparative method of data analysis (Hubbard & Power, 2003).

Revised data analysis. When beginning to use the constant comparative method, I realized that although the 50-Facts tests and student surveys were beneficial, two essential pieces were missing: a record of the number of problems solved by each student and a teacher observation log. These two missing pieces would help more clearly explain my two main research questions.

First, by recording the number of problems solved, a correlation between the amount of problems practiced and the results from the 50-Facts test could be more clearly understood. Drawing conclusions from my literature review, I am lead to believe that the more a student practices, the more proficient a student can become. Take, for example, two students with identical pre-test scores. If Student A solved 200 problems each day for 11 days while Student B solved 100, I would conclude that Student A's results would be higher in both the post- and sustained results tests. Again, showing correlation was possible due to having kept a record of the number of problems each student practiced each day.

The second added piece was my observation log. Keeping documentation of student behaviors during these sessions as well as analyzing student surveys provided me with a more well-rounded understanding of students' attitudes and motivations. Quite often, students are more likely to verbally express disdain during an activity compared to making written record of these disdaining feelings on a survey which will be analyzed by the teacher.

By including all four of these data sources, the two main research questions for this intervention are able to be answered much more completely.

Conclusion. This study uses a quasi-experimental, pre-test/post-test design. Taking place in a fourth grade classroom, this study's purpose was to analyze the effectiveness of a three-week intervention, measuring both student success and student motivation. Data was collected using four different methods: student test results, logging the number of facts answered, student surveys, and a teacher observation log. Data analysis was dual-layered. First, examining pre-, post-, and sustained results test scores in conjunction with the number of problems each student answered during each session uncovered underlying implications for different levels of success among each of the four groups. Second, documenting student behavior during each session as well as surveying students' motivation throughout the intervention may provide understanding to how a similar intervention could be modified to student preferences without losing the integrity of the intervention.

Most importantly, this intervention provides hope for educators that are looking for effective ways to help students become more proficient with multiplication fact recall. By looking at the results of this multiplication intervention, supporting student learning in any classroom can be done using structures, techniques, and data collection similar to this.

RESULTS

Overview of results. After implementing this three-week intervention, three main discoveries were uncovered. To begin, each mode of practice produced improved proficiency with multiplication facts (although different modes resulted in different growth levels). The second discovery was that the bottom two quartiles showed much improved proficiency rates, regardless of the mode of practice. Last, the class's overall level of motivation did not decline at the expected rate.

The first research question of this paper is, "To what degree will the mode of practice impact student achievement on recall of multiplication facts?" To collect data to show this, students were given a pretest, posttest, and sustained results- test on their multiplication fact recall. When viewing the results as a whole class, progress was shown throughout this intervention. The class's overall one-minute scores increased from pretest (36.4%) to post test (55.8%), but the score did drop down to 49.0% during the sustained-results test. The class's three-minute scores increased throughout, starting at 88.7% on the pretest and scoring an identical 95.4% on both the post test and sustained-results tests (see Appendix B). Looking closer at the three-minute results, noting that eleven students had already maximized this score is important. While the post test and sustained results tests three-minute scores are identical, five out of six of the students in the bottom quartile showed progress. Also, four students who scored 100% on their posttests missed a total of six problems on the sustained-results test. That slight decrease helps explain the lack of class growth from the three-minute posttest to the three-minute sustained-results test.

Now knowing that the class average was improved during the three minute scores, how did each mode of practice compare? After the results were calculated, each intervention group showed positive growth, some at fascinating extents (see Appendix C). Comparing the pretest and sustained results tests, the Multiplication.com group increased their average one-minute score by 19.9% and their three-minute score by 5.9%. The flash card group increased their average one-minute score by 30.1% and their three-minute score by 11.0%. The XtraMath group increased their average one-minute score by 55.9% and their three-minute score by 9.9%. Finally, the paper-and-pencil group increased their average one-minute score by 35.7% and their three-minute score by 3.3%.

Looking at the amount of problems solved in conjunction with the quality of practice could help explain these results. Starting with XtraMath, this group took a placement test to figure out which facts each student needed more practice learning. As a result, they spent a majority of the time practicing with what they needed to work on the most. While their group only solved an average of 112.1 problems per 10 minute session, the third highest average of this intervention (see Appendix D), these problems were almost entirely at each child's instructional level. Next, the flash cards (11.0% and 30.1%) and paper-and-pencil (3.3% and 35.7%) groups showed comparable three-minute test results. These two groups solved the largest amounts of problems during each session (flash cards solved 209.5; paper-and-pencil solved 179.2). Also, the groups followed identical patterns with multiples as detailed by various mathematical experts (Van de Walle, 2004; Silbert, J., Carnine, D., & Stein, M., 1990; Wong & Evans, 2007). Learning with this progression in mind ensured that students would master easier facts and apply that learned knowledge to more difficult facts. Finally, the Multiplication.com group showed the least three-minute growth in comparison to the other groups (5.9% in three-minutes; 19.9% in one-minute), which could largely be credited to the significantly lower amount of practice (57.1 problems per session, over 50% fewer problems than the next highest group). Additionally, this group only focused on one multiple at a time whereas the other three groups focused on a minimum of multiplying with four multiples during each session. Taking these results into consideration, the data implies that the mode of practice used should be one that not only has an appropriate amount of questions, but these questions as best utilized when they target each student's appropriate needs.

When analyzing the results from different quartiles, the results are promising (see Appendix E). The top quartile showed minimal fluctuation (9.5% in first minute, -0.3% in three minutes), which is largely due to the fact that this results are nearly maxed out to begin with. The second quartile also showed promising growth of 14.3% during the first minute, but a drop of 2.7% in three minutes was shown as well (mostly as a result of one student's 14.3% decrease; all other students in this group scored 98% or higher). Next, the third quartile showed the largest growth (80.9% in first minute, 8.0% in three minutes). These students had lots of room to grow with their one minute scores (starting at an average of 14.8 problems solved and ending with an average of 26.8 problems solved), but their three minute scores started at 90%. While there wasn't much room for growth in three-minutes, each student was able to score 96% or higher. Finally, and perhaps most promising, the bottom quartile showed immense growth with both one-minute and three-minute scores (64.6% in first minute, 40.3% in three minutes). Considering that these students not only had lots of room to grow in both their one- and three-minute scores, this group received lots of essential practice to show significant improvement. They received the necessary practice, and while only 1 out of the 6 students achieved 100% on their three-minute score, each student showed growth with multiplication fact proficiency.

The second research question this paper focuses on asks, "To what degree will the mode of practice impact student motivation related to recall of multiplication facts?" Each student participated in a Multiplication Intervention Survey at the end of each week (see Appendix A). Students were asked to provide feedback on the intervention, including motivation toward their mode of practice (on a scale of 1 to 10), expected sustained-results outcomes, and possible alterations to the intervention that would lead to the best results.

Looking at the students' motivation levels for each mode of practice (see Appendix F), the Multiplication.com group showed the highest level of motivation throughout the intervention, although this level declined (8.5/10 after the second week; 7.2/10 after the third week). Three of the seven students agreed that continuing multiplication.com was the best way for them to achieve proficiency: "Because you can do fun games and practice your facts," said one student. Another stated, "Because it helps me get quicker with math facts." The third simply stated, "Because it is better." This high motivation level may be due to the fact that most students in this group spent about as much time playing leveled games as they did answering multiplication problems. As written in my observation log, on several occasions, students spend between 60 and 70% of their time trying to pass a level of a particular game to get to the next set of questions, which took up the other 30-40% of the session's time.

The other three groups' motivation levels slightly increased from Week 2 to Week 3 (paper-and-pencil from 6.1-7.0, XtraMath from 4.6 to 4.7, and flash cards from 2.9 to 3.3). Four of the six in the paper-and-pencil group suggested that they thought their mode was the best practice method and would continue using it. Two students mentioned how the method of practicing was appropriate: "If you practice the same way [as you take the test] you'll get better" and "Because it really motivates me to write my numbers faster and helps me a lot." I also observed and recorded how all but one student in this group consistently tried to finish the entire packet of problems, a task which I assumed was impossible when starting this intervention (about 250 problems in 10 minutes equates to less than 3 seconds per problem). For the next group, only one of the six students in XtraMath considered using this website again: "Because it helped me and it might help other people as well." Three others in this group wanted to continue using computers for Multiplication.com, stating, "I chose that method because XtraMath just makes me feel pressured but Multiplication.com doesn't", "Because it's the most fun place. You can pick what you want [to play]", and "It's a good way to practice 5-11s!" These students were almost completely engaged each session, but I also recorded how apparent it was that they were looking for other methods of practice at the end of these three weeks. Finally, and perhaps most adamantly, the flash card group selected every other practice mode but flash cards. One student answered, "Because Multiplication.com and XtraMath you get to have fun and you learn. Flash cards…you just learn." He continued to scribble notes in the margins of the survey, stating, "No more flashcards!" a total of three times. During one of my discussions with this group, one student mentioned how I told her mom that flash cards weren't the best choice: "But you told my mom that you didn't like flash cards. Why do we need to practice them?" "Because we are going to see if they work well or not," I replied. "Do we really have to do this for the next eleven days?" she responded. "Just give it your best for these ten minutes. It's not that long, and if you give it your best, who knows how much you will improve?" I replied. Conversations similar to this one were held with this group almost daily.

Moving away from analyzing each practice group, students as a whole class varied on their analysis of their motivational levels throughout this intervention. Responses could be classified into four different groups: five students' levels decreased; five maintained their exact motivational levels 6/10 or higher from the second to third weeks; seven maintained their exact motivational levels 5/10 or lower from the second to third weeks; nine students' levels increased throughout the duration. Because of these results, implications for a schedule modification could be made. Rather than keeping students in the same practice groups during these three weeks, students could be offered to practice a variety of methods, especially considering the overall success of each group. Students could even be allowed particular choices on specific days. As a student who showed the smallest growth, solved the fewest amount of problems, and was observed as being the least motivated during this intervention mentioned, "Add some new things to it!"

Conclusion. When looking back over these results, each mode of practice was successful, but the rates of success differed. Also, motivation levels varied, as there was variation of decreasing levels, high and low maintained levels, and increased levels. Because of these two factors, offering students an opportunity to use all four modes of practice should be considered. This alteration with the modes of practice throughout the intervention could lead to improved motivation throughout this multiplication intervention.

DISCUSSION AND SUMMARY

Summary. The focus of this study was to design and analyze the effectiveness of a three-week multiplication intervention. Specifically, two research questions were targeted: "To what degree will the mode of practice impact student achievement on recall of multiplication facts?" and "To what degree will the mode of practice impact student motivation related to recall of multiplication facts?"

This three-week intervention consisted of eleven ten-minute practice sessions. Students were given a pre-test to rank their automaticity of multiplication fact recall and then placed in one of four practice groups (XtraMath, Multiplication.com, flash cards, and paper-and-pencil) based on those ranks. During the first eight practice sessions, students were given a multiplication table to assist their responses when needed; no multiplication table was provided during the final three days. At the end of this intervention, students were given a post-test similar to the pre-test. Three weeks after the intervention, students were given another similar test to evaluate their sustained results.

Data was collected in different ways. Students completed a survey at the end of each week, and a teacher observation log (including the amount of problems solved and student discussions) was kept during each session of the intervention. The results from each 50-facts test was also used to show change in proficiency.

From this intervention, one could establish that each of the four modes of practice can lead to a higher level of proficiency. XtraMath and paper-and-pencil seem to be the most valuable for its groups of students, as students from each group showed substantial one-minute and three-minute growths. Additionally, these two groups maintained an acceptable motivational level while practicing.

Conclusions. From these results, two main implications are present. First, students clearly befitted from this extra practice time. While there was one student who could already answer all 50 facts in one minute, the rest of the class showed continuous signs of improvement throughout this intervention. Second, taking into consideration the varied growth rates and motivational levels per group, the possibility of offering a variety of opportunities for practice could more positively influence student growth and motivational levels.

When focusing on the literature reviewed earlier in this paper, particular points have been supported. First, offering two groups (paper-and-pencil and flash cards) the progression of facts investigated in the literature review (Van de Walle, 2004; Silbert, J., Carnine, D., & Stein, M., 1990; Wong & Evans, 2007) led to similar results. This could be a result of the students having all multiplication facts scaffolded in a manner that almost ensured proficiency achievement with easier facts before moving on to more difficult facts. Conversely, neither the XtraMath nor the Multiplication.com group followed this progression. XtraMath almost exclusively practiced facts at an individually scaffolded manner. This could explain that while the XtraMath group answered a fewer amount of facts than the paper-and-pencil and flash card groups, they were practicing facts specific to their needs. The Multiplication.com group practiced whatever they wished. A progression of multiplication facts (in addition to the lowest number of problems answered) was almost entirely avoided, which may explain their lower amounts of growth.

Since the end of this intervention, the students have had a chance to work with equivalent fractions, multiplying whole numbers by decimals, and calculating the perimeter of polygons and the area of rectangles. From the literature review, different authors mentioned how students' anxiety levels can be influenced by their understanding of basic facts (e.g., Beck & Clark, 1997; Pekrun, 2006; Geist, 2010). From my classroom observations, I have noticed that many more students are willing to share their ideas when solving more difficult concepts without fear of answering multiplication facts incorrectly. Math anxiety with basic mathematical facts has all but completely vanished from our classroom.

This intervention began at the beginning of February. Since the pretest was given to determine which group each student as in, the class has taken a 50-facts test every three weeks. As of the end of the sustained-results test, six students are still working towards 100% proficiency within three minutes. Knowing that more support was necessary than the planned intervention, those six students are given support daily. Because of the results of the sustained-results test, each of the six are given class time to have a chance to work on XtraMath. They have also been offered the opportunity to work with flash cards and paper-and-pencil practice at school, and they are encouraged to use Multiplication.com at home. Because of these findings, I will be able to continuously support these students through the end of the school year, continuing to track their growth over the next several school weeks.

Another step from this intervention could be to rearrange the use of the different modes of practice. Knowing that these practice methods seem to vary with student proficiency outcomes as well as motivational levels, allowing students to use these different modes could lead to not only higher proficiency levels, but also higher motivational levels. For example, if creating another three-week intervention, students would have choices each day. Assuming four days of practice each week, during the first two days, the class could choose between paper-and-pencil and XtraMath since these seemed to be the most effective. On the third day, they could choose between paper-and-pencil, XtraMath, and flash cards. During the fourth day, they could choose from any of the four modes of practice detailed in this paper. Allowing choice should not only allow motivation levels to remain high, but may also allow students to practice in a manner they wish to practice rather than in a manner which they were required to.

Recommendations for future research and practice. As a result of this teacher research, several areas of future research should be considered. To begin, while this research focused on multiplication facts, what are some ways to successfully build proficiency with addition, subtraction, and division facts? Second, looking closer at considering memory systems of the brain, do students who struggle with multiplication facts have common capacities of working memory? If so, how can this capacity be utilized to help students eventually achieve proficiency? Next, while this intervention focused on four different modes of practice, what are the implications for practicing in a particular way? Does writing, speaking, or keying in answers have an impact on proficiency levels? Also, aside from these four, what are other effective ways of practicing multiplication facts? Finally, looking at longitudinal studies, might there be correlations between a fourth-grader's multiplication proficiency level and his or her mathematical academic performance in high school?

While this thesis has been an extensive focus on one concept of one curricular area, my discoveries throughout the duration of this paper have been beneficial when considering my other graduate studies and the outcomes of my students. Earlier in the graduate program, my cohort read two books that supported the idea that students can learn at high levels with appropriate practice, internal motivation, and necessary coaching. These books also encouraged me to look for more literature in connection with these concepts, further extending my knowledge of knowing how to support learners. At its core, I have learned that all students within a class will need different amounts of practice, different levels of support, and different learning opportunities. Because of this, teaching lessons as a whole class isn't the best answer. Many students already arrive with the necessary background knowledge to be successful. In the example of multiplication, these would be the students who can skip count, are proficient with addition and subtraction facts, and have a basic understanding when to use multiplication. Other students, however, may not have these areas mastered yet. From this research, I now know that teachers need to be prepared to provide these students with not only the lesson's focus, but also opportunities to continuously build background knowledge in order for the lesson's focus to be understood. Skip counting by eights, for example, could precede a lesson involving strategies for multiplying by eights. The students that do not need to practice those skills could be working independently with more difficult tasks. Teaching in this manner allows all students to learn at their developmental levels, which in turn allows each student to improve during each lesson rather than falling behind or becoming bored with the ease of the lesson.

In final analysis of this discussion, this research has been a positive experience for my students. The class seems to have less anxiety when working with more difficult mathematical concepts. Students that needed effective and appropriate levels of practice received the opportunity to achieve proficiency. Originally thought to be detrimental to student motivation, the class maintained an overall positive attitude during these practice sessions. Finally, and most importantly, the students have seen the positive effects of practice. Knowing that when practicing in a determined manner, they can improve their skills with anything from mathematics to musical instruments.

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Appendix

Appendix A

Multiplication Intervention Survey **Name:___________________________#:____**

Directions: Think back on this week's multiplication intervention before answering the questions.

1. Circle your group's practice focus.

Flash Cards	Multiplication.com	XtraMath	Paper and Pencil

2. How motivated were you to practice your facts this week?

|---------- |---------- |---------- |---------- |---------- |---------- |---------- |---------- |---------- |---------- |

1 2 3 4 5 6 7 8 9 10

(Not at all) (Very)

3. How much did you think practicing this way helped you? (Circle One)
   a. It helped a lot!
   b. It helped some.
   c. It helped a little.
   d. It didn't help very much.
   e. It didn't help at all.

4. What do you think is the best way to help you get quicker with math facts? (Circle One)
   a. Flash Cards
   b. Multiplication.com
   c. XtraMath.org
   d. Paper-and-Pencil
   e. Something Else (Please list):_______________________________

5. Look at how you answered question four. Why did you choose that method?

____

____

6. What do you expect your best score for your 50-Facts test to be?
   a. One-Minute Time (out of 50): ____________/50
   b. Three-Minute Time (out of 50): ____________/50

7. How would you rank yourself when it comes to answering multiplication facts? (Circle One)
   a. Super speedy
   b. Pretty fast
   c. Okay
   d. Not very good
   e. Terrible

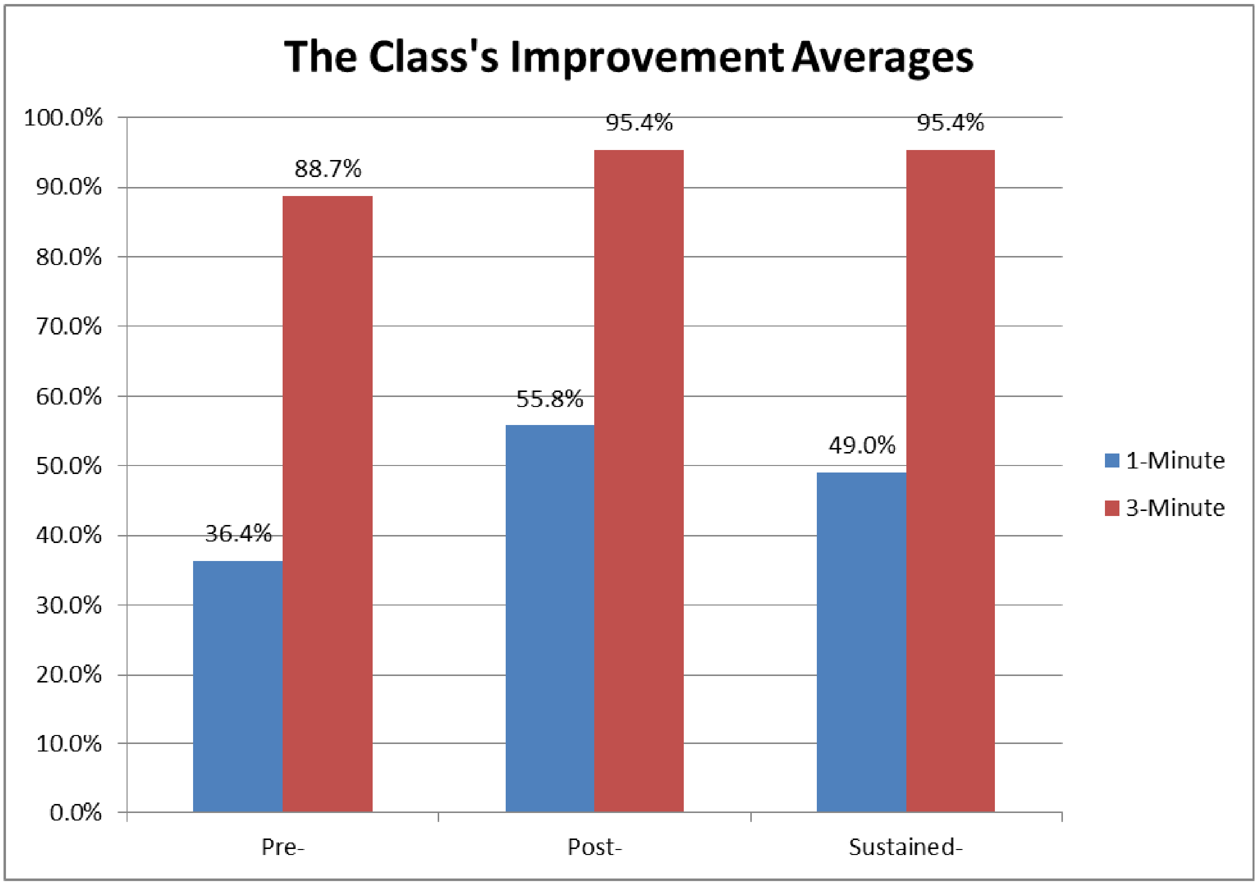
8. How could this multiplication intervention be better, or do you like it the way it is?

____

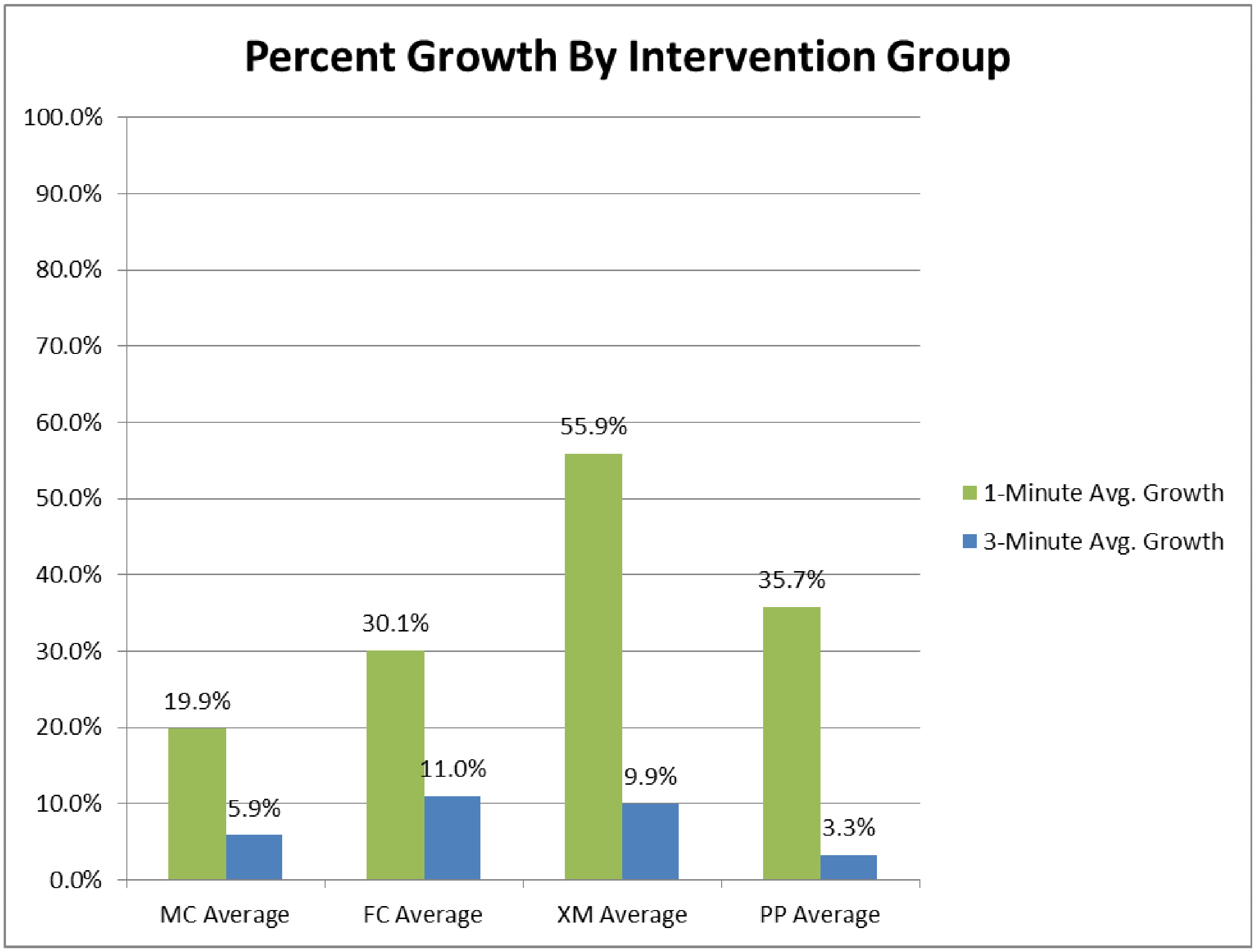
____

____

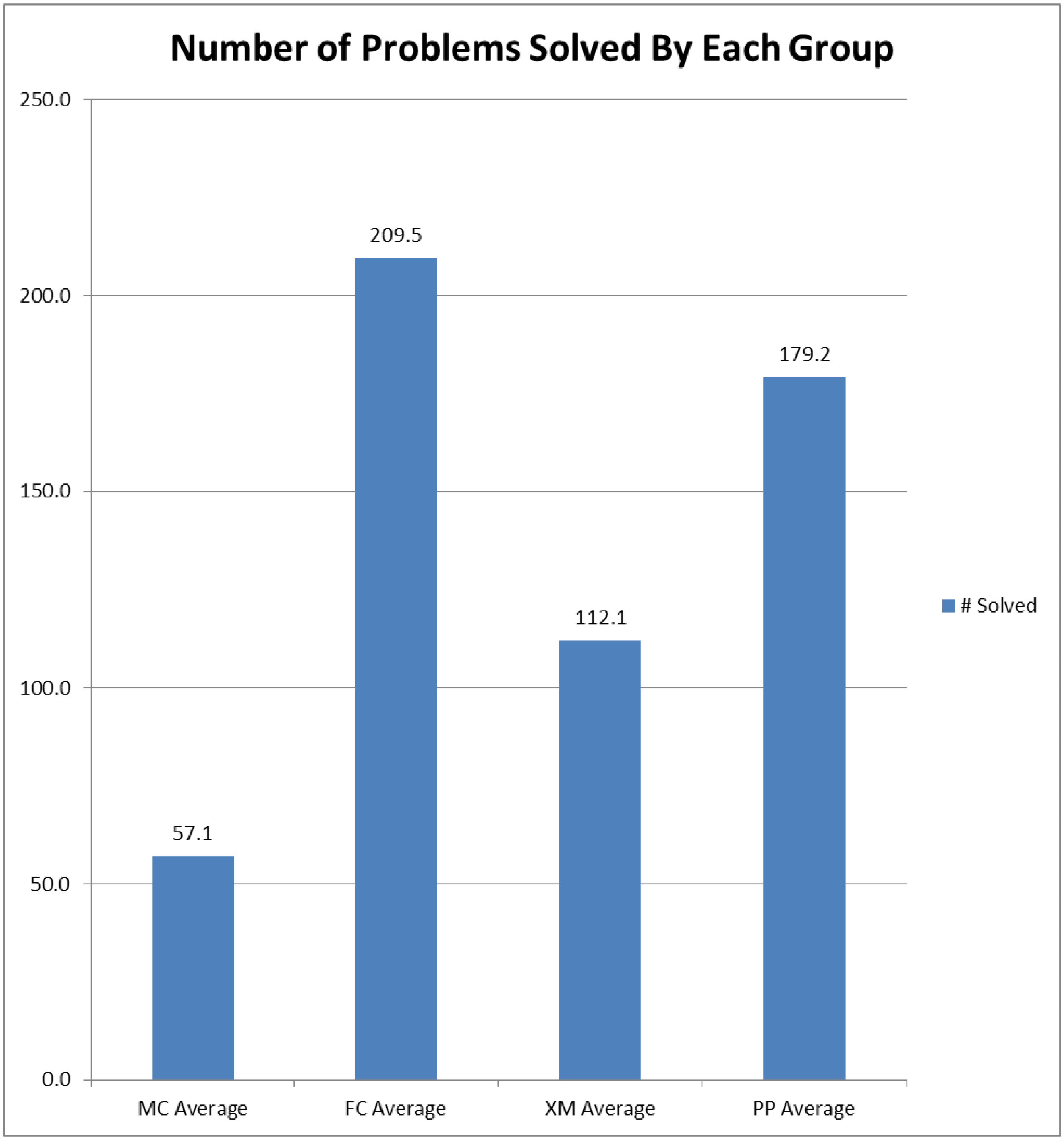
Appendix B


The Class's Improvement Averages
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
36.4%
88.7%
55.8%
95.4%
49.0%
95.4%
Pre-
Post-
Sustained-
1-Minute
3-Minute

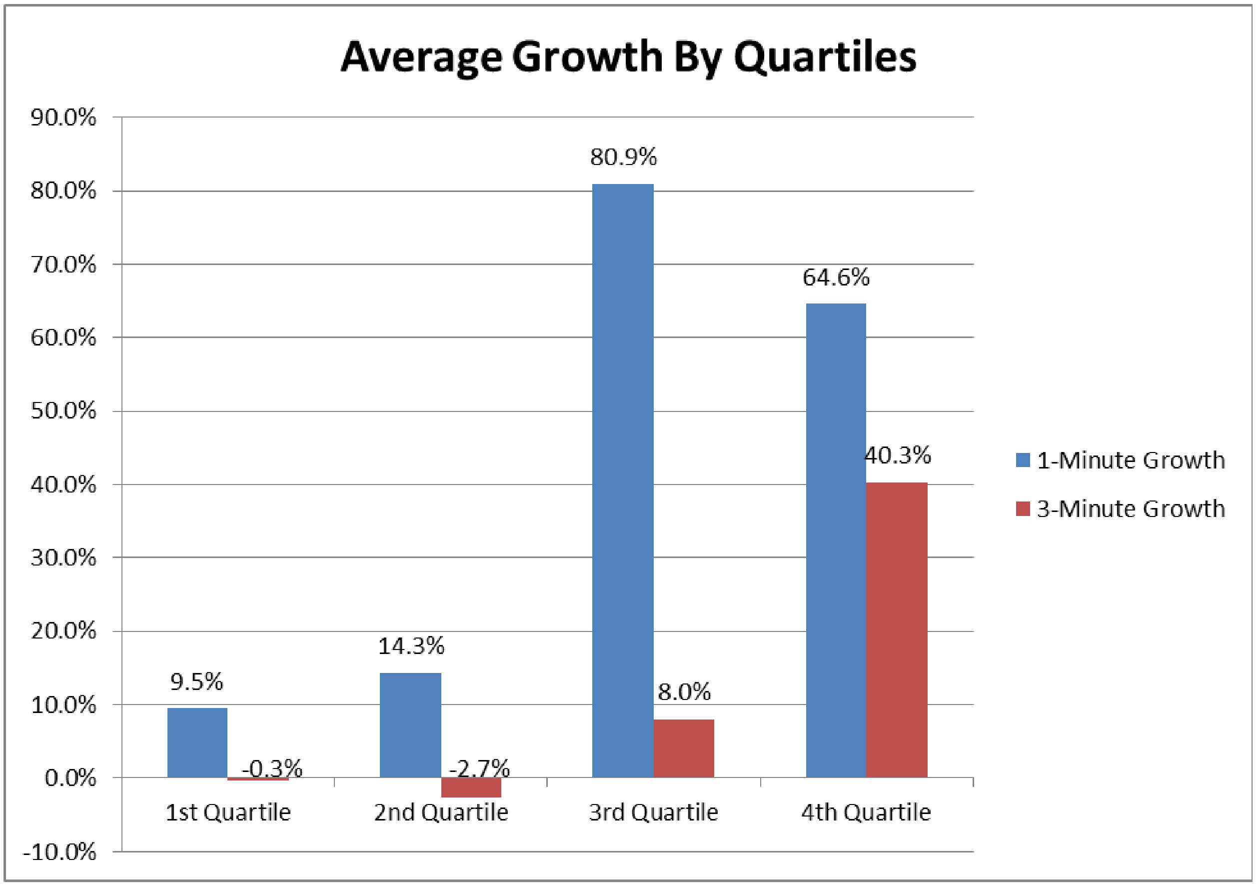
Appendix C


Percent Growth By Intervention Group
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
19.9%
5.9%
30.1%
11.0%
55.9%
9.9%
35.7%
3.3%
MC Average
FC Average
XM Average
PP Average
1-Minute Avg. Growth
3-Minute Avg. Growth

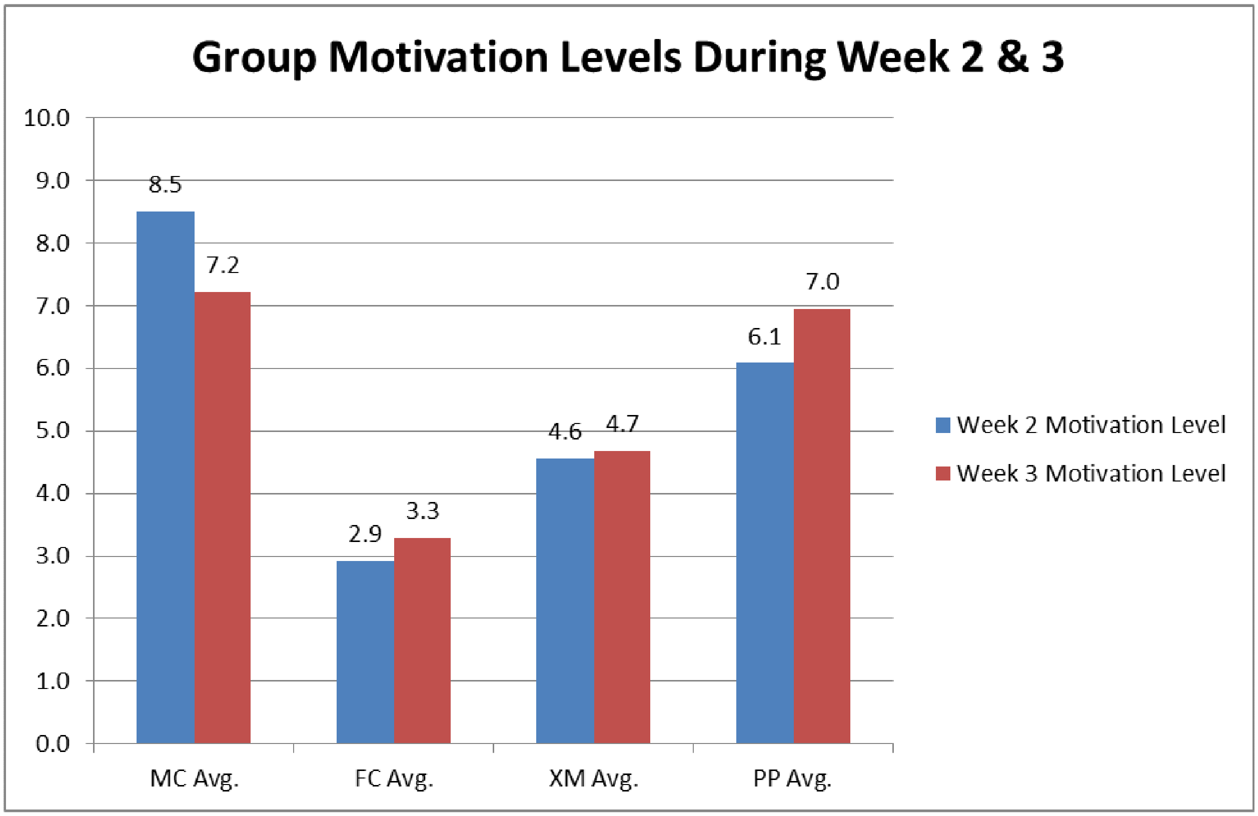
Appendix D


Number of Problems Solved By Each Group
250.0
200.0
150.0
100.0
50.0
0.0
209.5
179.2
112.1
57.1
Solved
MC Average
FC Average
XM Average
PP Average

Appendix E


Average Growth By Quartiles
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
-10.0%
9.5%
-0.3%
14.3%
-2.7%
80.9%
8.0%
64.6%
40.3%
1st Quartile
2nd Quartile
3rd Quartile
4th Quartile
1-Minute Growth
3-Minute Growth

Appendix F


Group Motivation Levels During Week 2 & 3
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
8.5
7.2
2.9
3.3
4.6
4.7
6.1
7.0
MC Avg.
FC Avg.
XM Avg.
PP Avg.
Week 2 Motivation Level
Week 3 Motivation Level