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Effectiveness of a Class-Wide Peer-Mediated Elementary Math Differentiation Strategy

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Effectiveness of a Class-Wide Peer-Mediated Elementary Math Differentiation Strategy

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by

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ABSTRACT OF THE DISSERTATION

Effectiveness of a Class-Wide Peer-Mediated Elementary Math Differentiation Strategy

by

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Doctor of Philosophy, Graduate Program in Education
University of California, Riverside, June 2017
Dr. H. Lee Swanson, Chairperson

Approximately 60% of classroom students have insufficient math skills. Within a Multi-Tiered Systems of Support (MTSS) framework, teachers can implement core differentiation strategies targeted at improving math skills of an entire class of students. Differentiation programs are developed in order to target academic skills of groups of students with varying levels of math proficiency. Considering the diverse levels of math proficiency in typical elementary classrooms, core enrichment programs can be highly effective in improving math skills of these students. However, it is important that teachers implement core differentiation programs that are evidence-based. Past research has supported the use of the PALS-Math differentiation program to improve math skills. The current analysis evaluated the effectiveness of the PALS-Math program using a modified pairing procedure. However, the current analysis found that implementing the PALS-Math differentiation program was not effective at improving the overall math skills of students when compared to the control group. Implications and limitations of the current study will be discussed.

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Effectiveness of a Class-wide Peer-Mediated Elementary Math Differentiation Strategy

According to the most recent Nation's Report Card, 56% of United States fourth grade students have below proficient math skills. Regarding students classified as economically-disadvantaged, the proportion of students with below proficient math skills increases to 75% (NAEP, 2015). Since the publication of No Child Left Behind (NCLB, 2001), a movement of school accountability has progressed with the goal of improving academic achievement of students across the country (Lee & Reeves, 2012). Within NCLB, math was identified as a subject that has served as a gauge of the progress of U.S. public school students. More recently, the Every Student Succeeds Act (ESSA) was passed as a replacement of NCLB. Although the Every Student Succeeds Act does provide more flexibility to states and provides focus on other aspects than just testing when considering a schools achievement, testing in the area of math is still mandated under the new law (Congress, 2015).

Reviewing past data shows that the math skills of United States students currently rank 25th out of 30 advanced nations (Baldi, Jin, Skemer, Green, Herget, & Xie, 2007). Accordingly, public school student math proficiency is becoming increasingly important in the current society (Harniss, Carnine, Silbert, & Dixon, 2010). This emphasis on math skills has led to an increase in the importance placed on standardized math test scores over the past few decades as a means to show the progress of math students in the United States (NAEP, 2013). However, a significant deficit continues to exist between the overall math skills of United States elementary students and students from other developed countries. This deficit has led to increased concern on the part of educators and non-educators alike on how best to improve the math skills of public school students (Bender, 2007).

For students with an Individualized Education Plan (IEP), the numbers are even more concerning. Based on the most recent Nation's Report Card (NAEP, 2015), only 16 percent of students with an IEP were found to have proficient or above levels of math skills. Within the State of California, that number decreases to only 10 percent of students with proficient or above math skills.

Math deficits tend to be a problem throughout a students' education. Thus, it is highly important that these students receive services designed to increase their math skills (Calhoon & Fuchs, 2003). The material that a student is required to master will only continue to increase in the level of difficulty as they progress through their education (Riley, 1997). Students with a math deficit in elementary school have the highest level of risk for being identified with a math deficit during their secondary education (Duncan et al., 2007; Gersten & Chard, 1999).

In fact, secondary students receiving special education services have been found to perform basic addition facts at the same level as a third grade student with no math disability (Fleischer, Garnett, & Shepard, 1982). These results are troubling considering the importance of math skills for daily living. Math proficiency has been found to be related to successful employment as well as successful independent living (Patton, Cronin, Bassett, & Koppel, 1997). Interestingly, mathematical proficiency is even more predictive of successful employment than reading skills. Adults with deficient reading skills still have higher employment prospects than adults with deficient mathematical skills (Rivera-Batiz, 1992).

Math Assessment and Instruction

Several difficulties exist within the area of math instruction. Rivera and Bryant (1992) is a seminal article that published the best practices in the area of math assessment and instruction. Their recommendations continue to affect the interpretation of math research (e.g., Burns, Codding, Boice, & Lukito, 2010). Rivera and Bryant (1992) stipulated a set of principles for math instruction that should be used to guide the math instruction that takes place within classrooms. These research-based principles include:

- Materials used for teaching skills and concepts should be varied,
- Differentiate instruction based on classroom needs,
- Students should be able to explain academic skills and concepts,
- Use records of performance to show students their growth,
- Students should be able to speak the mathematical language,
- Use aids to elicit student responses,
- Activities should improve concrete, representational, and abstract math skills,
- Math instruction should not overly rely on student workbooks,
- Instructional approaches should be used to ensure comprehension and mastery of skills and concepts,
- Math drills should only be used to provide meaningful math practice,
- Use current knowledge to better build upon new concepts,
- Help students understand how math can be used in their daily lives,
- Mathematical skills should be taught to improve problem-solving skills (Rivera & Bryant, 1992).

Furthermore, Rivera and Bryant (1992) asserted that classroom math instruction must include (1) teaching specific skills; (2) monitoring student progress in order to make good instructional decisions; (3) teaching thinking strategies; (4) focusing on mastery and generalization; (5) using modeling, prompting, and feedback; (6) providing students with math problems that can access various mathematical reasoning abilities; and (7) including thematic instruction that can help students understand how math skills can be utilized beyond the period of classroom math instruction.

As math instruction takes place, students must increase their skills in five distinct areas concurrently (e.g., numbers and operations, geometry, algebra, measurement, and data analysis; NCTM, 2006). When determining the type of instructional techniques that should be used for math instruction, Rivera and Bryant (1992) encourages using an instructional hierarchy that includes five distinct stages for learning math. The instructional hierarchy theorizes that as students undergo math instruction, they can be classified as being in one of these five stages of math learning. These five distinct stages begin with the acquisition stage, fluency stage, maintenance stage, generalization stage, and finally the adaptation stage (Rivera & Bryant, 1992). However, it is common that teachers do not provide students opportunities to progress through all five stages (Rivera-Batiz, 1992).

Acquisition Stage of Learning. Students within the acquisition stage of math learning have little or no understanding of the math skill or concept the teacher is targeting. Students need practice opportunities coupled with the guidance of the teacher. Rivera and Bryant (1992) specify that practice opportunities should not include having students complete several mundane tasks expecting these tasks will adequately target skills such as double-digit addition. They refer to this ineffective instructional strategy as passive arithmetic instruction (Parmar & Cawley, 1991). According to Rivera and Bryant (1992), effective instructional strategies that should be utilized to instruct students within the acquisition stage should include (1) the use of manipulatives in order to demonstrate an understanding of a math skill or concept, (2) teachers' explanation of the process used in performing a math skill, (3) creating and answering questions in multiple ways that can help a student understand different ways a math skill or concept can be utilized, (4) students working with their peers to help solve problems. Corrective feedback and reinforcement can also be very useful strategies used for students within the acquisition stage (Rivera & Bryant, 1992).

Proficiency Stage of Learning. As students progress from the acquisition stage into the proficiency stage, they exhibit a basic understanding of a particular skill. However, they lack automaticity, and they tend to make simple mistakes (Burns et al., 2010).These students have learned and understand how to exhibit a particular math skill or concept. However, these students still need to better develop their competence regarding these skills or concepts (Burns et al., 2010). These opportunities for practice should be unique to the opportunities the student has had in the past, and they should be interesting to the student in order to better engage the student in the instruction. Substantial research has been conducted validating peer tutoring as a strategy that can help improve math fluency (e.g., Rivera & Bryant, 1992; Rohrbeck, Ginsburg-Block, Fantuzzo, & Miller, 2003).

Beyond Acquisition and Proficiency of Math Skills. Although there are five distinct stages of math learning, math acquisition and math proficiency stages have received the most attention during the instruction that takes place within the classroom. It is often a problem within the classroom that teachers focus on teaching a specific math skill, and quickly move onto another math skill (Rivera & Bryant, 1992). However, the learning process is incomplete until students have been allowed the opportunity to progress through the maintenance, generalization, and adaptation stages of learning (Rivera & Bryant, 1992). Students need to fully understand how to apply a math skill to their daily lives before they begin learning a new math skill. As the name suggests, students within the maintenance stage need practice that will allow them to maintain their current levels of performance (Burns, 2004). Strategies that can be used within the maintenance stage include learning centers, seatwork, and continued unique opportunities for practice that interest the students (Rivera & Bryant, 1992).

The generalization of math skills occurs when students need to apply their math skills across people, materials, and settings. Students can be expected to apply these skills to games that elicit the use of these skills in settings that are more relevant to their daily lives. Self-monitoring has also been suggested as an instruction strategy that could be used for these students. Finally, the adaptation stage is the last stage that a student will progress through before it can be suggested that they are ready to begin learning a new math skill or concept. The primary goal for students within the adaptation stage of learning is developing skills related to using their understanding of math skills or concepts to solve problems. For these students, teachers can continue to use thematic units and daily living skills (e.g., managing a budget, planning meals) to improve their skills related to the adaptation of their math skills (Rivera & Bryant, 1992).

Math Instruction within an MTSS Framework

Multi-Tiered Systems of Support (MTSS) is a strategy that has been hypothesized to improve low academic achievement in the area of mathematics (Geary, 2011). Within an MTSS framework, students are identified that have a suspected math deficit. This identification process is more commonly known within the schools as “screening.” Students identified as having a possible deficit will then receive math intervention services that are targeted toward their specific skill deficit (e.g., single-digit addition; Glover & Vaughn, 2010).

Implementing an MTSS framework can also help a school evaluate the quality of the instruction taking place within each classroom. Ideally, screening results will show that approximately 75% of students within a classroom have proficient academic skills (e.g., reading or math). However, if the proportion of students within a classroom does not meet this standard, it is likely that more students are in need of intervention services than a school’s resources can meet (Glover & Vaughn, 2010). Considering recent suggestions that effectiveness of an intervention appears to be negatively related with group size (Wanzek & Vaughn, 2007), schools should avoid establishing intervention groups with a size larger than approximately six students. Consequently, in instances when the number of academically at-risk students exceeds school resources, students who have been identified as having a possible academic deficit must be targeted within their core instruction (Bender, 2007).

Several recommendations have been suggested for consideration as strategies that could be utilized to improve the achievement gap. These recommendations include standards-based instruction, curriculum alignment, improvement of teachers’ skills through professional development and evaluation, community involvement, and many other research-based initiatives. However, regardless of how much evidence-based support these strategies have developed, the problem of student achievement in failing schools still persists (ACT, 2006; Education Trust, 2006a; Education Trust, 2006b). Instructional differentiation has been validated as a strategy that can be used to improve academic achievement of students regardless of socioeconomic status (Beecher & Sweeny, 2008). Schools often regard instructional differentiation as a nonessential component of instruction. However, when student interests related to learning are considered, student academic engagement increases (Reis & Fogarty, 2006; Del Siegle & McCoach, 2005).

Within a typical upper-elementary classroom, student math skills can range from as low as 1st grade math skills and as high as high school level math skills (Bender, 2005). In the past, teachers have focused on the use of direct instruction as the primary method of increasing student math skills (Glover & Vaughn, 2010). However, as diversity increases within public school classrooms, direct instruction is not sufficient for targeting the wide range of math skills and different learning styles that might be present within the classroom (Tomlinson et al., 2003). Compounded with the excessive number of students with academic underachievement, teachers need to be able to implement instructional strategies that can be better targeted toward the needs of these students in need which schools are not able to include in intervention services (Bender, 2007).

School-Wide Enrichment Model

The School-wide Enrichment Model (Renzulli & Reis, 1985) is currently the most widely known and accepted model of school enrichment (Davis & Rimm, 2004). The School-wide Enrichment Model revolves around the Enrichment Triad Model that can be used by educators to provide a model of structure for incorporating enrichment into several different areas of the school day. Type I enrichment utilizes activities that are designed to expose students to types of experiences that they will likely not experience in the classroom. Type I activities should expand students' curiosity, while remaining consistent with the standards taught in the classroom. An example of a Type I activity would include taking students learning about astronomy to a planetarium or using a special weight-scale that shows students how much they would weigh on the moon. Type II enrichment programs include instructional strategies that promote critical thinking, problem solving, affective training, and learning the process of learning. Type III enrichment programs are highly advanced, and include types of activities that provide students with opportunities to assume the role of firsthand inquirer. Specific initiatives that are suggested include:

- School-wide Enrichment teams;
- interdisciplinary, differentiated units of study;
- differentiated lesson plans across the curriculum;
- extended day enrichment programs;
- comprehensive staff development; and
- accountability and assessment measures (Renzulli & Reis, 1985).

Beecher and Sweeny (2008) spent eight years implementing the model at an elementary school in an urban setting. Students within the school were performing in the 30^{th} percentile on district and state assessments in math, reading, and writing prior to the beginning of the study. Forty-five percent of students within the school qualified for the free and reduced lunch program. By the end of the longitudinal study, 75% of the school's students were identified as culturally or linguistically diverse, while 30% of students were classified as an English Language Learner. Although the period of implementation took eight years, the school benefited greatly from the adoption of the differentiation-based model. State testing results in students being classified as being in one of three categories (remedial, proficient, goal). Gains in the number of students classified within the “Goal” category were substantial. The proportion of low socioeconomic students within this category increased from 32% at the beginning of the implementation period to 60% at the end of the 8-year implementation period. The discrepancy between low socioeconomic status and high socioeconomic status decreased from 40% during the first year of implementation to only 15% following the 8th year of implementation. In the area of math specifically, this discrepancy was only 7% following the implementation. Furthermore, again following the implementation, the proportion of low socioeconomic students classified within the “Remedial” category decreased from 28% to only 4% (Beecher & Sweeny, 2008).

Proportions of White and Hispanic students within the “Goal” category both increased roughly 5%, while the proportion of Black students increased roughly 20%. The largest gains occurred among Asian students at the school where the proportion of students within the “Goal” category increased over 60% over the period of the enrichment implementation. Gains were also observed in the proportion of students classified within the “Remedial” category. Although the proportion of Asian and Black students within this category were 23% and 21%, respectively, before the implementation period, no students from these ethnicities were classified in the “Remedial” category following implementation. The proportion of White students classified within the “Remedial” category decreased from 13% to 4%, and the proportion of Hispanic students within this category decreased from 22% to 7% (Beecher & Sweeny, 2008).

A key component of the school-wide enrichment model is the inclusion of academic differentiation strategies that can be used to improve the academic skills of a diverse group of students (Renzulli & Renzulli, 2010). Curriculum differentiation within the classroom has been found to allow above average students the opportunity to avoid continued practice of an already mastered skill, and allows for opportunities to work on more related tasks that are more appropriate for their skill level (Reis, Burns & Renzulli, 1992).

Peer-Mediated Math Instruction

Peer-mediated instruction within the area of mathematics is an effective instructional strategy for improving math skills of heterogeneous groups of students (Kunsch, Jitendra, & Sood, 2007). Peer-mediated instruction was developed due to the need of teachers to better target the skills of students with academic disabilities within general education classrooms (Greenwood, Maheady, & Delquardi, 2002). Although literature has shown both general education and special education classrooms to have low rates of student engagement (Montague & Rinaldi, 2001; Thurlow, Graden, Greener, & Ysseldyke, 1983); models of peer-mediated instruction (e.g., Class-wide Peer Tutoring) have been found to increase the engagement of students (Kunsch et al., 2007). The hypothesized reason behind this increase in engagement is due to the fact that more students have opportunities for response to the instruction than during teacher-directed instruction (Greenwood et al., 2002).

Traditional direct instruction provides students few opportunities to respond to the teacher. As instruction takes place, one student will occasionally be able to respond to teacher prompts. Furthermore, under this model, the students that typically do respond are not the students with possible skills deficits (Bender, 2007). However, within a peer-mediated program (e.g., PALS-Math), students are paired with a peer, and much of the instruction is directed by the students. This model provides a higher number of opportunities for response by all students regardless of their skill level (Greenwood et al., 2002).

Peer-Assisted Learning Strategies for Math

Peer-Assisted Learning Strategies for Math (Fuchs et al., 2009) is a core instruction differentiation program that was developed using the framework of peer-mediated instruction. PALS-Math was developed in order to target the acquisition, fluency, and generalization math skills of heterogeneous groups of students. A recent meta-analysis conducted by Rohrbeck and Colleagues (2003) found PALS-Math to be an effective enrichment program that could be implemented in addition to the already implemented math instruction. PALS-Math increases math skills of students with heterogeneous math skills, while also increasing the engagement of these students. However, as with any peer-mediated instruction, group heterogeneity contributes to the effectiveness of the program (Bender, 2007; Hoffman, 2002). Teachers implementing PALS-Math have reported increases in student engagement and student social development (Baker, Gersten, Dimino, & Griffiths, 2004).

One important aspect that must be considered is the alignment of PALS-Math with the recently adopted Common Core State Standards (CCSSI, 2010) that have been implemented in 43 states, including California. Although PALS-Math has not been updated since the introduction of the Common Core State Standards, PALS-Math does target the same skills as the Common Core State Standards. Both PALS-

Math and Common Core State Standards were developed based on recommendations and focal points outlined by the National Council of Teachers of Mathematics (CCSSI, 2010; NCTM, 2006).

PALS-Math Literature. Fuchs, Fuchs, Phillips, Hamlett, and Karns (1995) evaluated the effectiveness of PALS-Math across multiple elementary grade levels. The study included 40 elementary classrooms that were randomly assigned to either the treatment group (PALS-Math) or the control group (i.e., business as usual). Student math skills were evaluated on two different areas of math learning. Researchers administered the Math Operations Test-Revised (Fuchs, Fuchs, Hamlett, & Stecker, 1991) that was used to evaluate student math acquisition. Student math skills related to skill transfer was assessed through the Math Concepts and Applications Test (Stecker, Fuchs, & Hamlett, 1992). According to the evaluation, PALS-Math contributed to increased math skills when compared to their peers not receiving PALS-Math.

Fuchs, Fuchs, and Karns (2001) evaluated the effectiveness of PALS-Math on the early numeracy skills of Kindergarten students. Twenty Kindergarten classrooms were randomly assigned to either the treatment (KPALS) group or the control group (business as usual) over a 15 week period. Student math skills were evaluated using the Stanford Early School Achievement Test (SESAT; Madden, Gardner, & Collins, 1983). Statistical analysis was conducted only after disaggregating the data based on student skill level. The analysis revealed a negative effect for students with higher math skills. However, these results are contrary to what has been observed in other articles that evaluated PALS-Math data based on student math skill level (e.g., Fuchs et al., 1995). Results of the effectiveness of PALS-Math for students with average math skills and below showed a moderate effect when compared to their peers that were not receiving PALS-Math instruction.

Fuchs, Fuchs, Yazdian, and Powell (2002) implemented PALS-Math within first grade classrooms. Twenty first grade classrooms were randomly assigned to either the treatment (PALS-Math) or control (business as usual) group. Teachers that were assigned to the treatment group implemented PALS-Math for 16 weeks. Student math achievement was measured utilizing portions of the Stanford Achievement Test (Gardner, Rudman, Karlsen, & Merwin, 1987). Treatment fidelity was also measured twice during the program implementation using the Grade 2-6 Math PALS Implementation Checklist. The measure that was used within this article will be discussed further within the Methods Section of the current article. Overall, treatment fidelity for the 10 teachers exceeded 95% on both occasions of data collection. The results of the treatment fidelity data collection indicated that PALS-Math could be implemented with fidelity. One concern with the use of the Stanford Achievement Test within this study was that researchers divided the measure into questions that were or were not aligned with the PALS-Math program. Ninety-four of the 106 items administered during data collection were included in the analysis. The items included in the analysis were divided in either PALS-Math aligned items or non-PALS-Math aligned items. Non-PALS aligned items were rated as being aligned with the district's core math instruction program, but not PALS-Math. The rest of the questions that did not meet either of these standards were excluded from analysis. Student math skill improvement was significantly higher for items that were PALS aligned as compared to the items that were not aligned with the PALS-Math program (Fuchs et al., 2002).

Codding, Chan-Iannetta, George, Ferreira, and Volpe (2011) evaluated the effectiveness of PALS-Math on the early numeracy skills of Kindergarten students. Six Kindergarten classrooms were randomly assigned to either the first treatment (KPALS) group, the second treatment group (KPALS with goal setting) or the control group (business as usual) over a 12 week period. Students math skills were evaluated using the Test of Early Mathematics Ability (TEMA-3; Ginsburg & Baroody, 2003) and the Tests of Early Numeracy (TEN; Clarke & Shinn, 2002). These measures included Number Identification, Quantity Discrimination, and Missing Number measures. Statistical analysis revealed that the effectiveness of KPALS varied based upon the measure that was used. A moderate effect was observed based upon the Number Identification measure, while a very small effect was observed based upon the Missing Number measure (Codding et al., 2011).

Of the published articles reviewed evaluating the effectiveness of PALS-Math, none utilized a randomized controlled trial design. Furthermore, as mentioned previously, concerns do exist regarding the exclusion of assessment items based on their alignment with PALS-Math instruction. Other deficiencies of the articles evaluating the effectiveness of PALS-Math included reviewing disaggregated data based upon student level math skills compared to reviewing class-wide data and only including one teacher in either the treatment or the control group.

Within an MTSS framework, programs that are implemented within the classroom such as PALS-Math (Fuchs, Fuchs, Karns & Phillips, 2009) would be classified as Type II enrichment programs. More specifically, programs such as PALS-Math align with the previously mentioned initiative of differentiating lesson plans across the curriculum. Considering that a primary goal of the current study is to determine whether using a modified pairing procedure from the pairing procedure provided in the PALS-Math curriculum is more effective, it is important to provide the theoretical underpinnings that have led to the researcher's hypothesis. Current literature in the area of peer-mediated instructional strategies does not currently support any one single type of pairing procedure (Maheady & Gard, 2010). However, theoretical literature suggests that the most effective pairing procedure is one that allows for all pairs of students to be as heterogeneous as possible (Hoffman, 2002). The current pairing procedure recommended within the PALS-Math curriculum pairs students using a procedure where the student with the highest score on the pre-test measure will be paired with the student scoring the lowest on the pre-test measure. An example of the pairing strategy used within PALS-Math has been included in Figure 3 (hereafter referred to as Pairing Strategy A) that can provide better understanding of the principles surrounding differentiation. The current analysis hypothesizes that a pairing procedure that pairs students in a way detailed in Figure 4 (hereafter referred to as Pairing Strategy B) that will likely ensure that the heterogeneity of the pairs receiving the instruction remain consistent. To further illustrate this concept, Figure 5 provides a visual graph of the pre-test scores for each pair within Class 1 when using Pairing Strategy A, while Figure 6 provides the pre-test scores of each pair within Class 1 when using Pairing Strategy B. For Class 2, the same tables can be found in Figure 7 (Pairing Strategy A) and Figure 8 (Pairing Strategy B). If Pairing Strategy A had been used in the study, the difference in the pre-test scores for each pair within Class 1 would have ranged from 0 to 32. Similar differences are seen in Class 2 where the difference scores would have ranged from 1 to 31. However, because Pairing

Strategy B was used for the current analysis, the difference score for Class 1 ranged from 7 to 18, while Class 2 difference scores ranged from 12 to 20.

Purpose

The purpose of this study was to evaluate the effectiveness of PALS-Math, a class-wide peer-mediated math differentiation strategy, at improving elementary math skills based on the observed results from math curriculum-based measures. Although literature currently exists supporting the effectiveness of PALS-Math for improving elementary math skills, very few articles have been published evaluating the effectiveness of PALS-Math at the elementary level that adheres to the highest research standards. Due to the poor research standards that were in use in the area of education, the United States Congress passed The Education Sciences Reform Act of 2002 (Congress, 2002) establishing rigorous scientific standards that were used to evaluate educational programs. The components evaluated include utilizing randomized sampling, low attrition, equivalence of student pre-test scores, and research integrity. Deficiencies that have excluded articles from adhering to the highest research standards include insufficient units assigned to either the control or treatment condition, pre-test groups not being shown as equivalent, and the implementation of multiple math programs rather than PALS-Math alone.

Within the area of class-wide peer tutoring, a particular pairing strategy has not been identified as being most effective (Maheady & Gard, 2010). However, it is necessary within heterogeneous classrooms to pair students in a way that students with lower skills are paired with students with higher academic skills (Hoffman, 2002). Pairing procedures utilized within the PALS-Math program do not necessarily pair a student with high skills with a student with lower skills. For example, using the pairing procedures included in Figure 3, the student with 15th highest math skills is paired with the student with the 16th highest math skills. It is likely that this pair will be more homogeneous than if a pairing procedure is used similar to Pairing Strategy B. For this reason, a secondary goal of the current proposal will be to evaluate the effectiveness of a modified pairing scheme on the math skills of students. The modified pairing procedure was selected in order to ensure that student pairs remained heterogeneous (Fuchs, Fuchs, Mathes, & Simmons, 1996).

In order to assist in the understanding of the goal of this project, a logic model has been provided in Figure 1. The logic model illustrates the goals of the proposed project. Approximately 60% of public school students have below proficient math skills. The goal of the proposed project is to implement a class-wide peer-mediated math differentiation program (PALS-Math) in order to improve the overall math skills of students in public schools. Also, the differential effects of implementing PALS-Math using a modified pairing procedure (Pairing Strategy B) will be evaluated.

Research Questions

The following research questions were evaluated in this study:

1. To what extent do classroom teachers implement PALS-Math using a modified pairing procedure with fidelity?

2. To what extent does PALS-Math improve class-wide math skills when compared to a control group?

3. To what extent do teachers implementing PALS-Math find the program to be socially valid for their classroom?

This study focused on the implementation and effectiveness of a peer-mediated math differentiation strategy designed to improve the math acquisition and fluency of elementary school students.

Methods

Participants

Elementary school second grade teachers interested in implementing a class-wide peer-mediated math differentiation strategy were recruited to participate in the current study from a suburban school district in New York. Interested teachers were randomly assigned into either the treatment or control group. Random assignment occurred by pulling a teachers name and group membership from two hats. Five teachers (N = 96) expressed interest in participating in the study. Two teachers were assigned to implement the PALS-Math program, while three teachers were assigned to the control group. For the current sample, 60 students were in the control group, while 36 students were in the treatment group.

A power analysis was conducted using the statistical analysis program G Power in order to determine the sample size that would be necessary to detect an effect size of 0.59 at a power level of 0.80 using an ANCOVA. The effect size was selected based on past research reviewing the effectiveness of the PALS math curriculum on class-wide elementary math skills (Rohrbeck et al., 2003). Results from the power analysis shows that a total sample size of 90 students were necessary to obtain sufficient statistical power (0.80) to detect an effect of 0.59.

Data collected for the study was collected by the district responsible for the administration of the core instruction differentiation program. Approval to use the collected data was acquired before analysis. Also, after initial review from the

Institutional Review Board, the analysis was given exempt status due to the data having been collected then provided to the researcher.

Measures

Curriculum-based measures were utilized in the study in order to determine the overall effectiveness of the PALS-Math differentiation strategy. Curriculum-based measures are a formative assessment approach that can be used to quickly determine the level of math skills of a group of students. Published standards (AERA, APA, & NCME, 2014) dictate psychometric criterion by which assessment measures are assessed. Considering that curriculum-based measures are used to determine levels of math skills for a group of students, the reliability of these measures should be at least 0.80 for academic screening measures. An additional reason why curriculum-based measures were used for the analysis is due to the fact that they have been found to result in larger effect sizes when compared to standardized measures (Rohrbeck et al., 2003).

Mathematics Achievement. For the purpose of analyzing the effects of the PALS-Math differentiation strategy on elementary math skills, AIMSweb Math-Computation measures were utilized (Pearson, 2012). Although these measures do meet the assessment standards mentioned earlier, these measures were selected since a well-developed literature base has been established that math computation procedures are a reliable method of assessing basic math skills (Thurber, Shinn, & Smolkowski, 2002). Furthermore, these measures are administered using a time limit, which is suggested as necessary for a measure to adequately measure student math fluency (Burns et al., 2010). AIMSweb Math-Computation measures are administered in group format for 8-minutes per administration. AIMSweb Math-Computation measures contain 28 computation problems designed to evaluate students' basic math fact fluency (e.g., 10 + 5; 5 + 3 + 2).

The *AIMSweb Math-Computation* (Pearson, 2012) measures were selected for this study because of the evidence supporting the use of these measures as a universal screening resource. These measures were developed in order to assess students' basic math skills. Each Math Computation measure consists of 28-items. The measure were administered for 8-minutes in a classroom setting. The reliability of this measure has been evaluated, and found to be satisfactory for assessing the basic math skills of elementary students. The alternate form reliability of Math-Computation is 0.82. Inter-rater reliability for Math-Computation has been found to be 0.99. Split-half reliability was found to be 0.75. Construct validity for Math Computations measures has been measured with a coefficient of 0.73 when compared to the Group Mathematics Assessment and Diagnostic Evaluation (G-MADE; Pearson, 2012). The AIMSweb Math Computation measures were administered and scored by the district Math Intervention Specialist that was trained to administer the M-COMP measures through training offered by AIMSweb.

Core Instruction. Teachers within all classrooms included in the study utilized the Engage New York math curriculum as the core instruction in their classes. The district was in their third year of implementing the program. Within the Engage New York curriculum, 2nd grade students are expected to extend their understanding of base-ten notation, build fluency with addition and subtraction, use standard units of measure, and increase skills around describing and analyzing shapes. Students work on eight modules throughout the school year. Module one focuses on improving students' automaticity with base-ten concepts while also learning number manipulation with numbers up to 100. Teachers are expected to help students with this skill through providing multiple opportunities for the skills to be reviewed while also covering the skill through differentiated instruction. Module two introduces measurement and making estimates using units of length as well as using these skills within word problems. Within module three, students are expected to continue practicing their base-ten skills while also being introduced the skills needed to manipulate numbers up to 1,000. Module four is focused on strengthening the students' skills with units of measurement with the following units focusing on this skill while also increasing the understanding about how a unit measurement can be any group of numbers (e.g., 4 apples is a unit). The 2nd grade school year finishes with students working on the skills of describing and analyzing shapes in terms of their sides and angles. Students are also expected to be able to discuss the composition and decomposition of shapes to form other shapes. A primary goal of the modules is to increase students' understanding of the relationship of numbers. Students are also given many opportunities to work in groups in order to learn these concepts in a peer-mediated setting (Engage New York, 2013).

Treatment

Peer-Assisted Learning Strategies – Math. Peer-Assisted Learning Strategies Mathematics (PALS-Math; Fuchs et al., 2009) is a class-wide peer-mediated math differentiation strategy developed as a method of core instruction enrichment. PALS-Math has been found to be effective in improving elementary math skills of all students within a classroom (Rohrbeck et al., 2003). PALS-Math is implemented in a whole-class setting, and is developed to target the needs of a heterogeneous group of students. A list of skills targeted by the PALS-Math program have been included in Figure 2. The program partners students into pairs through alternative ranking procedures. An example of the modified pairing procedures has been provided in Figure 4. For the purpose of the proposed study, students were ranked based on results from the Math-Computation measure. Rohrbeck and colleagues (2003) suggested implementing PALS-Math based on the dosage of instruction taking place, rather than the number of weeks of instruction. Instruction dosage is equivalent to:

$$Dosage\ Hours\ = Instruction\ Duration \times Days\ Per\ Week \times Weeks\ Implemented$$

The PALS-Math differentiation program is designed to be delivered twice weekly for 30 minutes each day. Based on meta-analytic results (Rohrbeck et al., 2003), implementation occurred over a 16 week period. This equated to an overall instruction dosage of 16 hours.

The PALS-Math program is administered in a whole class setting where students are partnered based on the observed score on the math assessment. Teachers were trained to implement the PALS-Math program through a three hour training offered by the team that created the program from Vanderbilt University. Once students are paired, the member with the higher score on the pre-test measure was assigned as the “first Coach”, while the student with the lower score on the pre-test measure was assigned as the “second Coach.”

The PALS-Math program begins with five training lessons where student learn the PALS-Math procedures. Following these five lessons, students begin participating in the two primary activities of the program. PALS-Math sessions consist of two unique activities, Coaching and Practice. When one student is the coach, the other member of the pair acts as the “Player.” In Coaching, the Player works through a sheet of math problems as the Coach monitors their progress and provides correction, as needed. The Coaching activity last approximately 15-20 minutes. After the Coaching activity, the pair begins the Practice activity. During the Practice activity, each student works independently on a sheet of math problems for five minutes. After the five minute period, the pair members trade papers and grade each other’s work. During the first nine weeks, math problem sheets are focused on Computation exercises designed to improve the math fact fluency of the students. During weeks 9 and beyond, PALS-Math sessions are focused on applying these basic math facts to applied math problems.

Reinforcement Program. In accordance with the procedures outlined by the PALS-Math program, points were awarded to students using proper PALS-Math procedures (e.g., utilizing the PALS-Math correction procedure). During the Coaching activity, points are awarded by the teacher as they observe students exhibiting behaviors that are appropriate for the PALS-Math lessons. During Practice activities, as the students work through the computation or application math problems, they are being awarded points by their peer for each math problem they are answering correctly. Students track their total points on a provided point tracker page. After each lesson has been completed, the pair of students scoring the highest number of points wrote their names on a “Highest Scorers of the Day” poster, which was posted at the front of the classroom. Each student from the identified pair received a prize (e.g, eraser, pencil, sticker). These procedures were adopted from the current literature base evaluating PALS-Math (e.g., Calhoon & Fuchs, 2003). Also, at the end of the PALS-

Math implementation period, the teachers implementing PALS-Math received a $25 gift card for their assistance.

Treatment Fidelity. Treatment fidelity data was collected in order to insure the differentiation strategy is being implemented appropriately based on the manualized procedures. Data collection was performed using the Grade 2-6 Math PALS Implementation Checklist which is included with PALS-Math materials. The procedures for collecting treatment integrity data included classroom observations with data collection related to teacher behaviors, classroom set-up, and student behaviors. The Grade 2-6 Math PALS Implementation Checklist has been included for review in Appendix B. Treatment fidelity data was collected for each teacher implementing the PALS-Math differentiation program by the researcher. Treatment fidelity data was collected twice for each teacher at separate times within the program implementation. These procedures were adopted from research conducted evaluating the effectiveness of PALS-Math (Codding et al., 2011; Fuchs et al., 2002). For the purpose of data collection related to treatment fidelity, the unit of analysis was the teacher, not the student.

Modified Pairing Procedure. As discussed previously, past research has asserted that a pairing procedure within peer-mediated instruction that pairs students with more heterogeneous academic skills (Maheady & Gard, 2010). Considering this, Pairing Strategy B has been used for the current evaluation of PALS-Math. After completing the pre-test assessment, students are ranked based on their score on this assessment. In both classes implementing the PALS-Math program using the modified pairing procedure, 18 students were sorted into nine pairs. As seen in Figure 4, the student scoring highest on the pre-test (High Score 1) was paired with the student scoring 10th on the pre-test measure (Low Score 10). Students were then paired in descending order until the student with High Score 9 was paired with the student with Low Score 18. As shown in Figure 5 and Figure 6, this pairing procedure allows for the pairs to have more similar levels of heterogeneity.

Control Treatment. Students within the control group received instruction using the core math instructional program that is currently being implemented within the district. These students did not receive PALS-Math instruction. During the implementation, students within both the control and treatment groups received approximately 50 minutes of math instruction daily.

Social Validity. Procedures measuring the social validity of PALS-Math were utilized based upon the procedures used within PALS-Math research (e.g., Fuchs et al., 2002). The questionnaire measured the social validity of the PALS-Math program using a 5-point Likert-type scale. Teachers assigned to the treatment group were asked to complete the questionnaire once the 16 week period of PALS-Math implementation is complete. The questionnaire is included in Appendix C in order to review the questionnaire that was used for the study.

Statistical Analysis

Analyses for the first research question was conducted using an analysis of covariance (ANCOVA) statistical procedure:

$$Y_{ij} = \mu + \alpha_j + \beta_1(X_{ij} - \overline{X}.\,.) + \epsilon_{ij}$$

The reason that an ANCOVA was selected for the current analysis rather than a repeated-measures ANOVA was in order to ensure that any differences in the pre-test scores of the students are controlled for in the analysis. Considering that the mean pre-test score for the control group was 30.267 and the mean pre-test score for the treatment group was 27.722, the ANCOVA was chosen in order to ensure that any significant results can't be attributed to the differences within the groups' pre-test scores.

Student post-test scores on the Math-Computation measure were included in the model as the dependent variable, while student pre-test scores were included as a covariate. The independent variable was included within the statistical analysis (group status) as fixed effects. Students' group status was classified based on whether they are a student of a teacher that has been randomly assigned to implement either (1) PALS-Math using modified pairing procedures, or (2) no differentiation program within their classroom. For the variable of student group status, two levels were used (e.g., treatment or control). Student post-test scores were included as the dependent variable. Due to the nested nature of the analysis, teacher of instruction was included in the original analysis to determine if any significant differences existed between each teachers. However, because there were no significant differences between the teachers of instruction, this variable was excluded from the final analysis.

Regarding the question related to the treatment fidelity of the teachers' implementation, descriptive statistics were provided in order to determine the percentage of PALS-Math components that were implemented during the PALS-Math implementation (Fuchs et al., 2002).

As the hypothesized results were not observed, effect scores were calculated to determine the level of effect that each group exhibited. These calculations were conducted in order to provide objective data showing the varying levels of benefit between groups. The effect size formula that was chosen was done so because of the ability to decrease the amount of bias that might be present in the data because of the inclusion of the correlation between the pre-test and post-test administration of the achievement measures:

$$Hedges's\ G = \frac{(X_1 - X_2) - r(X_{1-pre} - X_{2-pre})}{\sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_1^2}{(n_1 + n_2 - 2)}}}$$

where r is the correlation between the pre-test and post-test measures ($r = 0.761$). A further benefit of this effect size calculation is the ability to calculate the observed effect within the treatment group relative to the control group (WWC, 2010).

Results

Assumptions of ANCOVA

Five separate assumptions were tested in order to ensure that the conducted ANCOVA was appropriate. These assumptions include normality, homogeneity of variance, independence, homogeneity of regression slopes, homoscedasticity, and linear relation between groups.

Normality. A Q-Q plot was developed to help determine whether the dataset satisfied the assumption of normality. The graph used to determine normality has been in Figure 9.

Homogeneity of Variance. In order to assess the homogeneity of variance for the collected sample set, a Levene's Test of Equality of Error Variances was conducted. The results show an insignificant difference of the error variances between groups (F (1,94) = 0.89). Therefore, the assumption of homogeneity of variance can be accepted for the proposed analysis.

Independence of Sample. Considering that the students participating in the current study were in five separate classrooms, it is assumed that the assumption of independence can be accepted.

Homogeneity of Regression Slopes. In order to determine whether the assumption of Homogeneity of Regression Slopes has been satisfied, an interaction analysis was conducted to determine if an interaction exists between the independent variable and the covariate. After reviewing the results from the analysis, it is clear that the assumption of Homogeneity of Regression Slopes has been satisfied ($F(1,92) = 1.036$).

Independence of Covariate and Treatment. Within an ANCOVA, it is assumed that the measure used as the covariate cannot be effected by the treatment being administered. Considering that the covariate used within the current study is the pre-test assessment, it can be assumed that the pre-test assessment data is independent of the PALS-Math treatment.

To what extent do classroom teachers implement PALS-Math using a modified pairing procedure with fidelity?

Past research has consistently shown that teachers are able to implement that PALS-Math program with a high level of fidelity (Calhoon & Fuchs, 2003; Fuchs et al., 2002). Therefore, it is hypothesized that the teachers included in the current analysis will have implemented the PALS-Math program with at least 95% fidelity based on the observations of the researcher using the fidelity checklist provided with the PALS-Math program.

In order to ensure the differentiation program was being implemented with fidelity, two observations were conducted for each teacher conducting the PALS-

Math program. During the classroom observations, data were collected using the Grade 2-6 Math PALS Fidelity Checklist which awards points for the adherence of teachers and students to the PALS-Math procedures. During the first observation, Teacher A had a fidelity score of 98%, while Teacher B had a fidelity score of 100%. During the second classroom observation, Teacher A had a fidelity score of 100%, and Teacher B had a fidelity score of 100%.

Both teachers included in the PALS-Math sample were able to implement the PALS-Math differentiation program with at least 98% fidelity. These data would suggest that implementation fidelity is not likely a contributing factor to any lack of growth observed within the students receiving the PALS-Math program.

To what extent does PALS-Math improve class-wide math skills when compared to a control group?

It is hypothesized that that the math skills of students receiving the PALS-Math differentiation strategy will increase significantly when compared to the math skills of their peers that are not receiving the math differentiation instruction. Past literature has shown that students receiving instructional differentiation in the area of math have shown significantly greater gains when compared to their peers not receiving these strategies (Calhoon & Fuchs, 2002; Codding et al., 2011). However, Fuchs and colleagues (2002) did not find any significant impact of implementing the PALS-Math program in the elementary classroom. Considering that Fuchs and colleagues (2002) utilized the traditional pairing procedure that is recommended with the PALS-Math program, it was hypothesized that the current analysis will show greater differences between the math skills of the students receiving the PALS-Math program and the students receiving core instruction alone because of the utilization of the modified pairing procedure.

Results from the Analysis of Covariance found there was no significant difference within the post-test scores of the Mathematics-Computation measure between the treatment and control groups after controlling for the pre-test scores (F (1,93)= 0.778; p = 0.38, MSE = 39.427). In fact, the difference between the mean post-test score of the treatment group and the post-test score of the control group was less than one point. Descriptive statistics between these groups have been included in Table 1. Analysis of the effect size shows that PALS-Math resulted in only a small positive effect when compared to the control group (g = 0.139). For complete ANCOVA results, refer to Table 2.

Considering the data from the current analysis, there were no significant differences between the math skills of the students receiving the PALS-Math program and those students receiving core instruction alone. These results considered with the results from past research (e.g., Fuchs et al., 2002) would suggest that the pairing procedure utilized within the PALS-Math program does not impact the effectiveness of the program as much as was expected.

To what extent do teachers implementing PALS-Math find the program to be socially valid for their classroom?

Past research (Fuchs et al., 2002) has found that the PALS-Math program has a high level of social validity with teachers implementing the program. For questions related to the effectiveness of the PALS-Math program to improve student math skills, teachers rated the program with an average score of 3.80 for high-achieving students, 4.40 for average-achieving students, and 4.00 for students with low math achievement. On questions evaluating the improvement of student social skills, teachers rated the program with a 3.90 for low-achieving students, 4.20 for average-achieving students, and 4.00 for high-achieving students. More mixed results were found when the teachers asked how feasible implementation will be without support. On this question, teachers' ratings ranged from 2 (where 1 = *not at all easy to use*) to 4 (where 5 = *very easy to use*).

Based on the results found in past research (Fuchs et al., 2002), it was hypothesized that the teachers will rate the PALS-Math program with at least a 4 on questions related to the improvement of their average and low achieving students' math skills, and at least a 3 out of 5 of high achieving math skills. Also, on questions related to the improvement of students' social skills, it was hypothesized that the teachers will rate the PALS-Math program with a 3 out of 5 for students with high achieving math skills and at least a 4 out of 5 on the improvement of the social skills of average or low achieving students. Although Fuchs and colleagues (2002) found inconclusive results when looking at the ease with which PALS-math could be implemented in a classroom without support, it is hypothesized for the current study that teachers will rate the program with a 4 out of 5.

When asked how effective the PALS-Math program was at improving the math skills of low-achieving students, both Teacher 1 and Teacher 2 rated the program a 3 out of 5. For average-achieving students and high achieving students, Teacher 1 rated PALS-Math with a 4 out of 5, while Teacher 2 rated PALS-Math as a 3 out of 5.

On whether the PALS-Math program increased the social skills of low-achieving students, Teacher 1 and Teacher 2 rated the program with a 4 out of 5. For the improvement of the social skills of average-achieving and high-achieving students, Teacher 1 rated the PALS-Math program with a 3 out of 5, while Teacher 2 rated the program with a 4 out of 5. When asked how easy it would be to implement the PALS-Math program in their classroom without support, both teachers rated the program with a 4 out of 5 indicating that the program is perceived to relatively easy to implement.

Discussion

To what extent do classroom teachers implement PALS-Math using a modified pairing procedure with fidelity?

Implementing any academic program must be done with a high level of fidelity in order to increase the level of effectiveness. With an average level of treatment fidelity of over 99% for both teachers, the PALS-Math program was followed very closely to the procedures detailed. Previous research (e.g., Fuchs et al., 2002) has established an expectation of at least a 95% adherence to the PALS-Math procedures. The practical implications of these data could encourage more teachers to utilize a program like PALS-Math to improve their classes overall math skills. A high level of treatment fidelity within the current analysis suggests that poor implementation of the PALS-Math program is unlikely within these two classrooms.

To what extent does PALS-Math improve class-wide math skills when compared to a control group?

Past meta-analytic evaluations of PALS-Math have found PALS-Math to lead to statistically significant differences between the treatment and control groups (Rohrbeck et al., 2003). However, current data did not reveal a statistically significant difference between the math scores of students receiving the PALS-Math differentiation instruction and the students receiving core instruction alone. Further supporting that the current data did not show any statistical significances, effect size analysis showed only a small effect for students receiving the PALS-Math supplemental curriculum when compared to the control group. Based on these results, it is recommended that teachers consider these results along with previous research conducted in the area of math differentiation to determine whether their classes will benefit from PALS-Math.

To what extent do teachers implementing PALS-Math find the program to be socially valid for their classroom?

Teachers implementing the PALS-Math program in their classes were asked to use the social validity rating scale in order to better understand their perceptions of the differentiation program. When asked about the effectiveness of the PALS-Math program at improving the math skills of students, Teacher 1 rated the program with a 3 out of 5 for their low achieving students. For students with average or high achieving students, Teacher 1 rated the PALS-Math program with a 4 out of 5. These results would suggest that Teacher 1 viewed the program as being more effective for the students with the lowest risk levels.

When Teacher 2 was asked about the effectiveness of the PALS-Math program to improve the math skills of their students, Teacher 2 rated the program with a 3 out of 5 regardless of the math achievement levels of the students being considered. These results would suggest that this teacher didn’t view the program as being very effective in improving the math skills of any of their students.

On questions related to the improvement of student social skills, Teacher 1 rated the PALS-Math program with a rated the program with a 4 out of 5 for students with lower level math skills. For students with average and higher level math skills, Teacher 1 rated the program with a 3 out of 5 on the improvement of their social skills. For these questions, Teacher 2 rated the program with a 4 out of 5 for all their students regardless of the students' math skills. When considering how easy it would be to implement the PALS-Math program in their classroom without support, both teachers rated the program with a 4 out of 5.

It is interesting to consider the differences between the teachers' ratings of the effectiveness of the PALS-Math program to improve their students' math skills versus the improvement of their students' social skills. Teacher 2 rated the PALS-Math program with a higher level of effectiveness at improving the social skills of their students than their math skills.

PALS-Math within an MTSS System

The results from the current analysis showed that students receiving PALS-Math as a supplemental differentiation program only exhibited a small effect in their math skills when compared to the control group. The current results would suggest that the utilization of a modified pairing procedure does not increase the effectiveness of the PALS-Math differentiation program. Within a multi-tiered system of support (MTSS), it is important that as many students benefit from the classroom instruction as possible in order to decrease the number of students in need of academic interventions.

Previous meta-analytic results (e.g., Rohrbeck et al., 2003) found an average effect size of 0.59 for groups receiving the PALS-Math curriculum. The results from the current analysis found an effect size (g = 0.139) lower than previous results. These results would suggest that using the modified pairing procedure does not increase the effectiveness of the PALS-Math differentiation program, and that the pairing procedure included in the PALS-Math program should be used. It is important to note that these data do not support the theoretical research conducted showing that the heterogeneous grouping of students provides for better academic outcomes (Harris, 2009).

High Performing Sample

It's important to consider how the composition of the sample that was collected could possibly impact the results found within the current analysis. Based on the AIMSweb cut scores, students with a score on the Math-Computation measure of 30 or above are considered to not be at-risk. Students with a score below 18 are considered to be in the high-risk range. For the control group, the mean score on the pre-test measure (30.267) is actually above the AIMSweb cut score. The mean of the treatment group (27.722) is only a few points from being considered no-risk, and would still be classified as being low-risk. When looking at the scores of the individual students, 32 of the 60 students in the control group had a score of at least 30, while 20 of the 36 students in the treatment group had a score in the no-risk range. When looking at the students that would be classified as high-risk, 11 of the 60 students in the control group would be in this category, while eight of the 36 students within the treatment group would be in the high-risk category.

It is interesting to consider the expected rate of improvement as noted by AIMSweb and the observed rate of improvement based on the collected data. For the control group, the observed rate of improvement was 0.31 points per week. Based on the expected rate of improvement for students with an after skill level, this rate of improvement was at the 55th percentile of all 2nd grade students tested using the

AIMSweb Math-Computation measure. For the PALS-Math group, the observed rate of improvement for these students was 0.44 points per week. When compared to the expected rate of improvement based on the AIMSweb recommendations, this rate of improvement was at the 65th percentile of all students tested using the AIMSweb Math-Computation measure. Based on these results, the rate of improvement of the PALS-Math group was greater than the rate of improvement of the control group. These data would suggest that there is some benefit to implementing the PALS-Math program in the classroom in addition to a core instructional program that does include peer-mediated or differentiation strategies.

Math Differentiation Strategies

The current data do further support the findings from past research evaluating the effectiveness of the PALS-Math program. Fuchs and colleagues (2002) also found no discernible effects of the program on elementary math skills. This study did use the traditional pairing procedure that is recommended by the PALS-Math program which would suggest that the effectiveness of the PALS-Math program is not easily influenced by the pairing procedure utilized.

It is important to consider how PALS-Math compares to other classroom math differentiation strategies that can be used at an elementary level. In an analysis of a peer-assisted learning strategy, Cook, Scruggs, Mastropieri, and Casto (1985) found this strategy to have an effect size of 0.60, and was significantly more effective than the peer-assisted reading strategy implemented. Another study evaluating the impact of a peer-assisted learning strategy found that students receiving the math differentiation strategy showed a 30 point increase on a math achievement measure while the control group only showed a gain of less than 1 point (Shamir, Tzuriel, & Rozen, 2006).

Davenport and Howe (1999) found that students that worked collaboratively during math instruction showed a greater difference in their basic math skills when compared to students that did not work collaboratively. Fantuzzo, Davis, and Ginsburg (1996) found similar results where students receiving peer tutoring showed a greater effect than students receiving an independent instruction method. In fact, students receiving peer tutoring along with parent involvement showed greater gains than students in either of the other groups evaluated. Within this student, parent involvement consisted of three components where the level of communication between home and school was increased, parents were also taught the math facts that the students were learning, and parents celebrated the gains of their children.

Billington (1995) provided small group instruction to whole classes and administered a math assessment to all students. The experimental group was able to complete the assessment collaboratively, while students within the control group completed the assessment independently. Students then completed the assessment a second time at a later time. Students that were able to complete the initial assessment collaboratively had a significantly higher score on the delayed assessment. These data would suggest that collaboration between students promotes retention of math instruction. While this evaluation did not provide a different type of instruction between the two groups, it does provide a possible factor that supports the effectiveness of any peer-assisted learning strategies.

The current literature base suggests that allowing students to work collaboratively during instruction or assessment leads to a higher level of learning and retention than having students working independently. However, it is important to note that much of the literature reviewing collaborative math strategies does include problem-solving instruction where students are taught how to check their peers work (e.g., Davenport & Howe, 1996; Shamir et al., 2006). Therefore, a critical component of any peer-assisted learning strategies is allowing students to work together while using problem-solving techniques.

Implications for Educators

The data have are presented within this study should be considered within the framework of peer-mediated math differentiation. The current literature has well-established that peer-mediated instruction is an effective strategy for improving academic skills of elementary students. However, these data found that there was no significant difference between the math skills of the students receiving the math differentiation instruction and the students receiving the core instruction alone. The implications of this could be used to help develop pairing procedures for educators considering implementing peer-mediated math instruction in their class. The current study utilized a pairing procedure where students are paired in a way that is different from the pairing procedure that is recommended with the PALS-Math program. The pairing procedure used within the current study pairs students with the goal of keeping the skills differences within each pair consistent, while the pairing procedure recommended with the PALS-Math program allows for the differences in the skill levels within each pair to vary. It is interesting to note that the pairing procedure used with the PALS-Reading program recommends pairing students by the procedure used in the current analysis.

A benefit of the current analysis is the evaluation of the effectiveness of the alternative pairing procedure. Past research (Fuchs et al., 2002) did not find a significant difference between the math skills of students receiving the PALS-Math differentiation program and those students receiving only core instruction. These results were found while using the traditional pairing procedure that is recommended by the PALS-Math program. Considering the results from both studies would suggest that changing the pairing procedure for the implementation will likely not lead to significantly higher math skills of the students receiving the PALS-Math instruction.

Limitations

A limitation of the current study is related to the sample size for the analysis conducted. A power analysis conducted prior to the beginning of the study indicated that 89 students would be satisfactory for the analysis. However, the observed power was only 0.152. Future studies directed at evaluating the effectiveness of PALS-Math would benefit from including a larger sample size that can allow for a greater level of statistical power. A larger sample size would also allow for analyses of how socio-economic status impacts the effectiveness of this program.

Another limitation of the study is the generalizability of the results. The sample was collected from a school in upper, rural New York. The racial diversity of the sample collected is much different from the typical classrooms found in states with large proportions of minority students (e.g., California, Texas). Also, there was a very low proportion of students that qualified for free or reduced lunch which is one of the best indicators of socio-economic status for school-aged students. The generalizability of any future replications of the current study would likely benefit from collecting a sample with larger levels of diversity.

Another limitation would be the inability to evaluate the effectiveness of the PALS-Math program to improve the math skills of students with differing levels of math skills. An original goal of the project was to determine if PALS-Math was more effective in improving the math skills of students with lower level math skills when compared to their higher achieving peers. However, the number of lower achieving versus average achieving versus higher achieving students was not large enough to have enough statistical power to conduct the analysis.

A possible limitation does exist in the inability to know whether the teachers implementing the PALS-Math program would be willing to implement the program in the future. In future versions of the social validity questionnaire, it would be informative to include questions related to the willingness of the teachers to implement the PALS-Math program in the future or whether they will recommend the program to fellow teachers needing to improve the math skills of their students.

Finally, it is a limitation that the core instruction program used by the teachers in the sample (Engage New York) did emphasize the importance of providing students with increased opportunities to gain automaticity through several strategies including differentiation through peer-mediated instruction. It is likely that the strategies used in the PALS-Math program do have some degree of overlap with the Engage New York program, which would lead to possible transfer effects. Future studies should consider the possibility of these transfer effects when a core instructional program does recommend strategies used within the treatment.

Future Directions

Before any reliable conclusions can be derived from the current analysis, a larger sample size would need to be collected. Any future research evaluating the effectiveness of PALS-Math should include a large enough sample size to account for attrition or random assignment issues. Although the current data revealed a large effect on the varying groups of students, the sample was too small to determine whether the difference between the treatment and control was statistically significant.

Future research in the evaluation of PALS-Math would also benefit from being conducted in a setting that is more similar demographically to schools that are commonly seen in more urban areas. Conducting this research would make it easier for practitioners in school settings to determine how the program might affect the math skills of their own students.

Future research conducted evaluating the effectiveness of PALS-Math should continue to evaluate the resulting data based on the varying levels of math skills within the sample. Past research has suggested that the PALS-Math program has differing levels of effectiveness for students with higher levels of math skills when compared to students with lower levels of math skills (Fuchs et al., 2002). It is beneficial for researchers and practitioners to understand how effective an academic program can be for every student in the classroom regardless of academic skill level.

Considering the components and the recommendations of the core curriculum that was being implemented in all classrooms (Engage New York), the core instruction does emphasize the importance of automaticity and does encourage the use of differentiation strategies as well as peer-mediated instruction. It is likely that several of the strategies included in the PALS-Math program are used commonly within the Engage New York curriculum.

Research conducted in the future evaluating PALS-Math as a classroom differentiation program would benefit from evaluating the differential effects of the

PALS-Math program at improving the math skills of students with varying levels of math skills. Within an MTSS framework, it is important to understand how academic programs can support students with suspected math deficits. Implementing programs that are effective at increasing the math skills of students with a math deficit can decrease the amount of students that will need support through academic interventions.

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Appendix A

Table 1

Descriptive Statistics by Treatment Group

Group	Pre-Test Mean (SD)	Post-Test Score (SD)
Control (*N* = 60)	30.267 (13.565)	35.217 (12.374)
PALS (*N* = 36)	27.722 (9.543)	34.806 (8.305)

Table 2

ANCOVA Results

Source	SS	df	MS	F	Sig
Corrected	6583.747	2	3291.874	64.945	.000
Intercept	3239.804	1	3239.804	63.918	.000
Pre-Test	6579.944	1	6579.944	129.816	.000
Group	39.427	1	39.427	0.778	.380
Error	4713.878	93	50.687		
Total	129318.000	96			

Note. R-Squared = 0.583

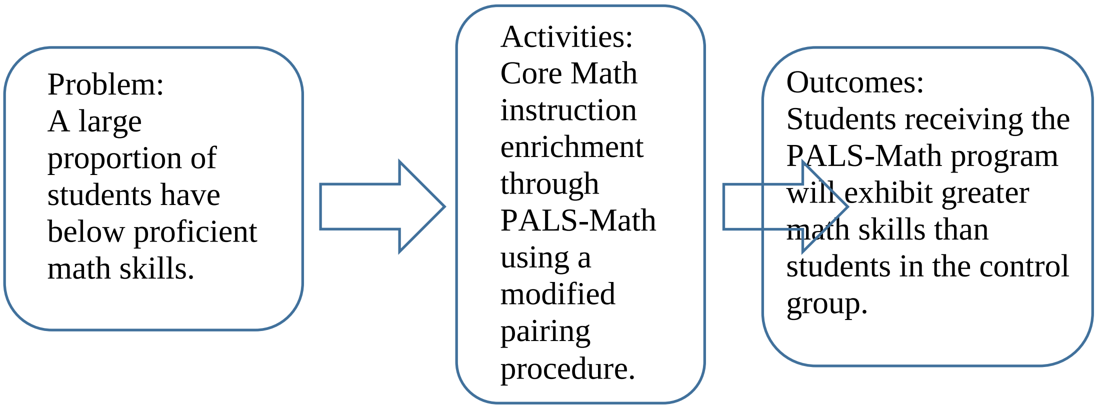

Figure 1. Logic Model

Broad Area	Topic	Focus
Computation	Adding Basic Facts	Basic Facts (0-18)
	Adding Without Regrouping	1-digit & 2-digit
	Adding With Regrouping	1-digit & 2-digit
	Subtracting Basic Facts	Basic Facts (0-18)
	Subtracting Without Regrouping	1-digit, 2-digit, 3-digit
	Subtracting With Regrouping	1-digit, 2-digit, 3-digit
Concepts and Applications	Applied Computation	Filling in blanks in addition and subtraction problems
	Charts and Graphs	Reading and interpreting bar graphs
	Counting	Counting by increments 2, 5, or 10
	Fractions	Writing fractions from shaded figures
	Measurement	Telling time to 15-minute intervals
	Money	Counting picture money
	Number Concepts	Comparing numbers
	Names of Numbers	Word form of numbers
	Word Problems	Addition, subtraction, and money (1-digit, 2-digit)

Figure 2. Skills Targeted by 2nd Grade PALS-Math

Pair Member A	Pair Member B	Pair Number
High Score 1	Low Score 18	1
High Score 2	Low Score 17	2
High Score 3	Low Score 16	3
High Score 4	Low Score 15	4
High Score 5	Low Score 14	5
High Score 6	Low Score 13	6
High Score 7	Low Score 12	7
High Score 8	Low Score 11	8
High Score 9	Low Score 10	9

Figure 3. Pairing procedure that is included with the PALS-Math program.

Pair Member A	Pair Member B	Pair Number
High Score 1	Low Score 10	1
High Score 2	Low Score 11	2
High Score 3	Low Score 12	3
High Score 4	Low Score 13	4
High Score 5	Low Score 14	5
High Score 6	Low Score 15	6
High Score 7	Low Score 16	7
High Score 8	Low Score 17	8
High Score 9	Low Score 18	9

Figure 4. Pairing procedure that has been utilized in the current study.

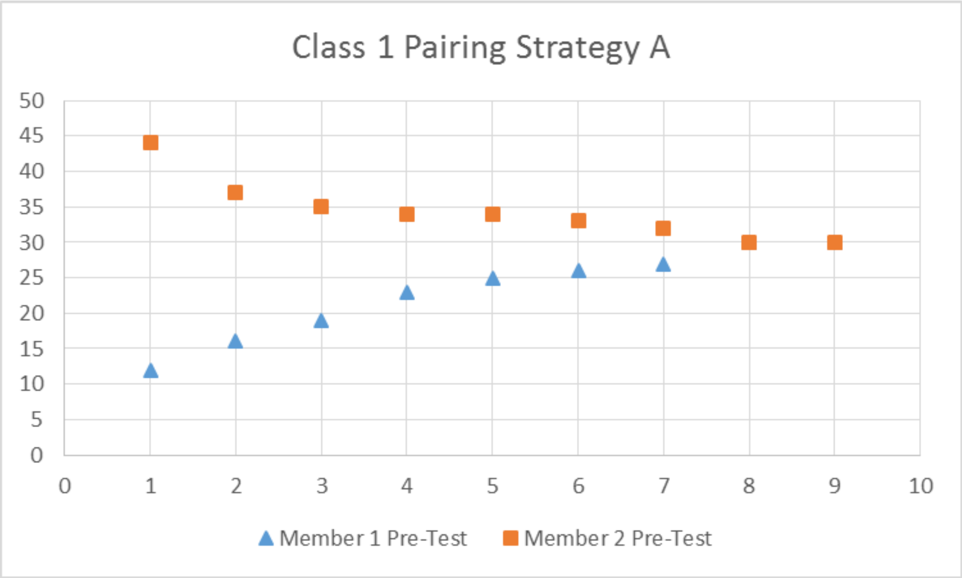

Figure 5. Pre-test AIMSweb math scores based on the pairing procedure utilized by the PALS-Math program.

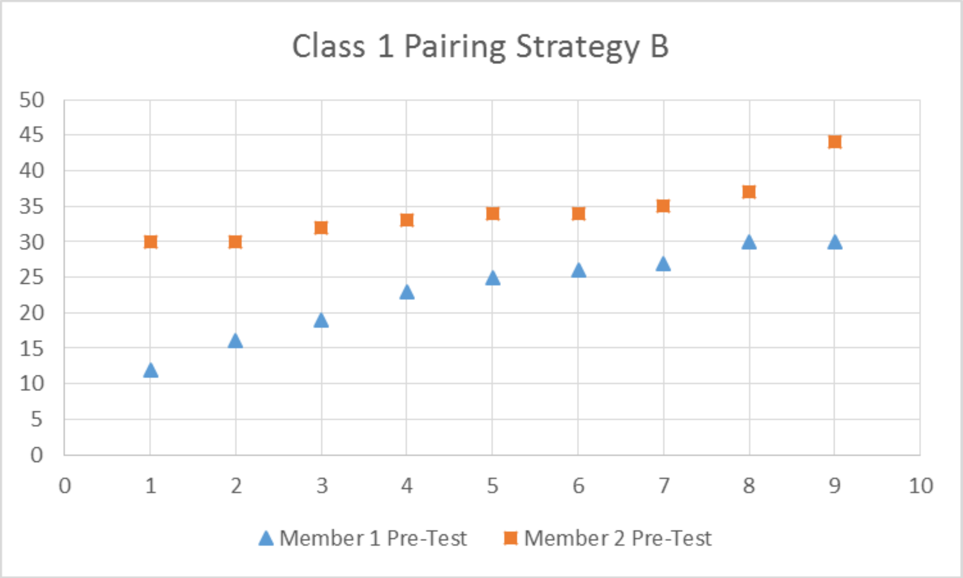

Figure 6. Pre-test AIMSweb math scores based on the modified pairing procedure utilized by the current analysis.

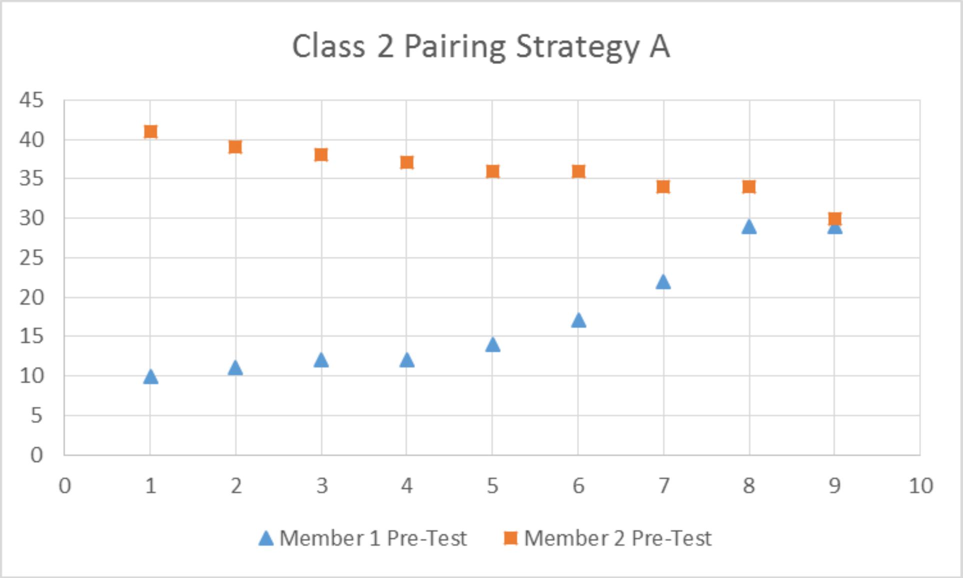

Figure 7. Pre-test AIMSweb math scores based on the pairing procedure utilized by the PALS-Math program

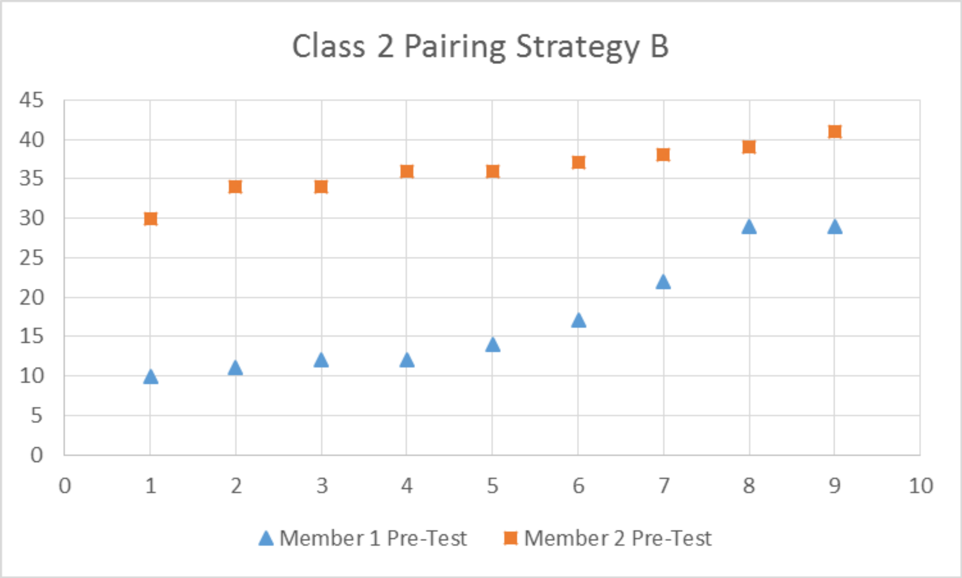

Figure 8. Pre-test AIMSweb math scores based on the modified pairing procedure utilized by the current analysis.

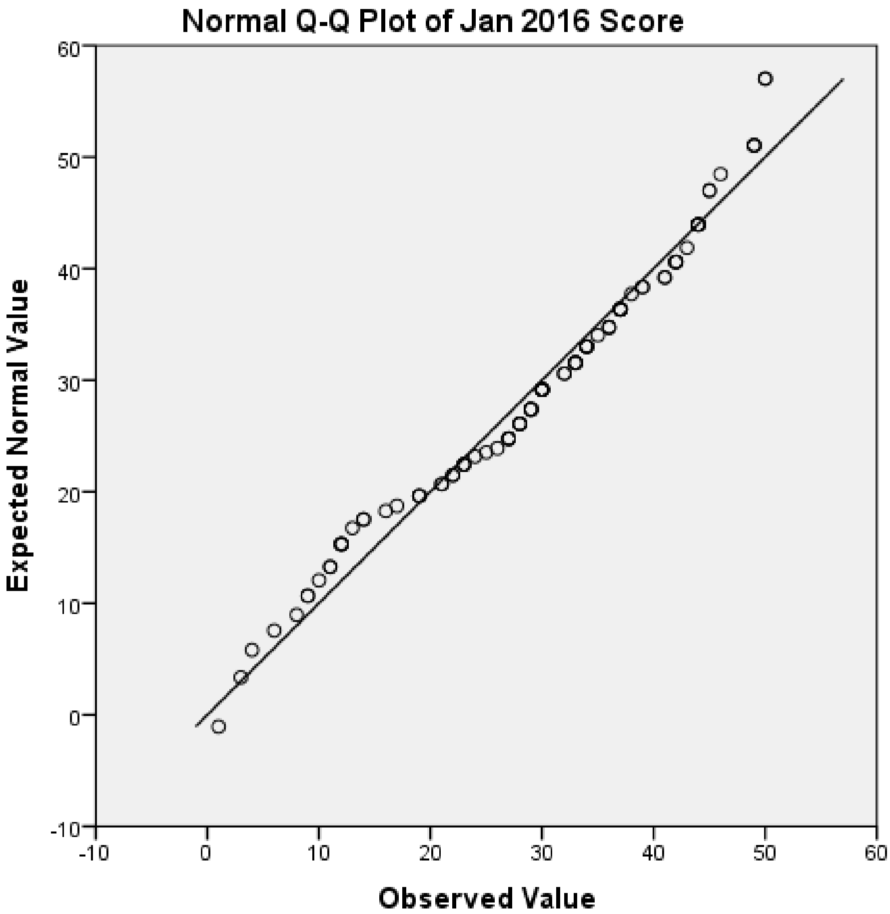

Figure 9. Normality Q-Q Plot

Appendix B

Grades 2-6 Math PALS Implementation Checklist

Teacher:_______________ School:_________________ Observer:_________

Timeslot:_______________ # of Students Present:________ Lesson #:_________

PALS OVERALL _______ Start Time _______ End Time

circle = behavior observed
blank = behavior not observed
crossed out = not applicable

Getting Ready for PALS

Teacher Behaviors

Value	
1	Announces it's time for Coaching
1	Students move to PALS places _______ Start Time _______ End Time (1-2 min.)
1	Teacher Reviews Coach's Question Sheet (if necessary)
1	Teacher Reviews Correction Procedure (if necessary)
1	Teacher reminds students when to switch roles
1	Teacher reminds students when to quit using Coach's Question Sheet and begin Self Talk
1	Teacher instructs students on new procedure, if applicable

Classroom Set-up

Value	
1	Higher performing math students are paired with lower performing math students
1	Students are seated next to their partners with Question, Point, & Coaching Sheet
1	Students should know who their partner is for the day (pairs are posted)
	<u>Teacher Materials</u>
1	Training materials, if needed
1	Timer
1	PALS Tutoring Command Card
	<u>Student Materials</u>
1	Coach's Question Sheet
1	Coaching Answer Sheet (Coach)
1	Coaching Sheet (Player)
1	Point Sheet (Coach)
1	Pencils

Comments:

Coaching

Teacher Behaviors

Value	
1	Coach and Player work together < or = 15 mins._______ Start Time _______ End Time
1 1	Teacher monitors every pair (1 pt for 75% of pairs 2 pts for every pair)
1	Teacher awards points throughout Coaching for good PALS behavior
1	Teacher provided positive feedback during Coaching
1	Teacher provided corrective feedback during Coaching

Student Behaviors

Pair observed _____________ & _____________

Value	
1	Coach uses Coach's Question Sheet for Row 1 (or until the stop sign on Applications)
1	Coach draws circles around correct digits
1	Coach corrects Player using Correction Procedure when a digit is incorrect
1	Coach listens to the Player self-talk for Row 2 (or until the flag on Applications)
1	Player listens to Coach and responds appropriately
1	Pairs switch jobs
1	Coach 2 uses Question Sheet for Row 3 (or until the stop sign on Applications)
1	Coach 2 draws circles around correct digits
1	Coach 2 corrects Player using Correction Procedure when a digit is incorrect
1	Coach 2 listens to the Player self-talk for Row 4 (or until the flag on Applications)
1	Player listens to Coach and responds appropriately

Comments:

Pair observed _____________ & _____________

Value	
1	Coach uses Coach's Question Sheet for Row 1 (or until the stop sign on Applications)
1	Coach draws circles around correct digits
1	Coach corrects Player using Correction Procedure when a digit is incorrect
1	Coach listens to the Player self-talk for Row 2 (or until the flag on Applications)
1	Player listens to Coach and responds appropriately
1	Pairs switch jobs
1	Coach 2 uses Question Sheet for Row 3 (or until the stop sign on Applications)
1	Coach 2 draws circles around correct digits
1	Coach 2 corrects Player using Correction Procedure when a digit is incorrect
1	Coach 2 listens to the Player self-talk for Row 4 (or until the flag on Applications)
1	Player listens to Coach and responds appropriately

Comments:

Pair observed _____________ & ____________

Value	
1	Coach uses Coach's Question Sheet for Row 1 (or until the stop sign on Applications)
1	Coach draws circles around correct digits
1	Coach corrects Player using Correction Procedure when a digit is incorrect
1	Coach listens to the Player self-talk for Row 2 (or until the flag on Applications)
1	Player listens to Coach and responds appropriately
1	Pairs switch jobs
1	Coach 2 uses Question Sheet for Row 3 (or until the stop sign on Applications)
1	Coach 2 draws circles around correct digits
1	Coach 2 corrects Player using Correction Procedure when a digit is incorrect
1	Coach 2 listens to the Player self-talk for Row 4 (or until the flag on Applications)
1	Player listens to Coach and responds appropriately

Comments:

Transition Time

Teacher Behaviors

Value	
1	Transition time takes no longer than 3 minutes_______ Start Time _______ End Time
1	Teacher stops Coaching
1	Teacher awards bonus points
1	Teacher reiterates good PALS behavior
1	Teacher has students put away coaching materials and prepare for Practice

Student Behaviors

Value	
1	Students are on task and remain in their seats listening during wrap-up
1	Coach 2 makes sure both names are on the Coaching Sheet
1	Coach 2 places the Coaching Sheet back in the Player's folder
1	Coach 1 place the Coaching Answer Sheet back in the Coach's folder
1	Coach and Player get out their Practice Sheets
1	Coach and Player write their names at the top
1	Coach and Player turn papers over immediately after information is recorded at the top

Practice

Teacher Behaviors

Value	
1	Begins activity
1	Stops activity after 5 minutes (or when almost everyone is finished)

Student Behaviors

Value	
1	Students work during entire Practice Time

Practice Sheet Scoring and PALS wrap-up

Teacher Behaviors

Value	
1	Has students exchange papers
1	Has students write their name in the "Scored by" space
1	Has Coach 2 get Practice Answer Sheet out of Coaching folder
1	Helps students with scoring if necessary
1	Has students return papers back to original Coach and Player
1	Has students check their point value by counting the number of circled problems
1	Has Coach 2 mark their points earned
1	Has Coach 1 mark their points earned
1	Has students replace Practice Sheets
1	Has students circle their point value
1	Has students raise hands for certain point values until the last pair is raising their hand
1	Has lead pair collect folders and everyone returns to their seats

Student Behaviors

Value	
1	Exchange sheets quickly
1	Write their names in the "Scored by" space provided
1	Coach and Player share answer sheet
1	Students circle correct problems appropriately
1	Students count the number of correct answers and write at top of Practice Sheet
1	Students give papers back to their partner
1	Each student checks their score by counting circled problems
1	Coach 2 marks points
1	Coach 1 marks points
1	Students replace practice sheets
1	Pairs circle total number of points earned
1	Coach 2 returns to seat

Comments:

Student Points	Teacher Points	Total Points
_______ ___%	_______ ___%	_______ ___%

Overall Suggestions/Comments:

Appendix C

Social Validity Questionnaire (Fuchs et al., 2002)

Overall, how much did PALS-Math increase the math achievement of your low-achieving students?

1…………………….2…………………..……3………………..………4……………...5

Not At all *Very Much*

Overall, how much did PALS-Math increase the math achievement of your average-achieving students?

1…………………….2…………………..……3………………..………4……………...5

Not At all *Very Much*

Overall, how much did PALS-Math increase the math achievement of your high-achieving students?

1…………………….2…………………..……3………………..………4……...………..5

Not At all *Very Much*

How much did PALS improve the social skills of your low-achieving students?

1…………………….2………..…………3………………..………4…………….……..5

Not At all *Very Much*

How much did PALS improve the social skills of your average-achieving students?

1…………………….2…………………..……3………………..………4……………..5

Not At all *Very Much*

How much did PALS improve the social skills of your high-achieving students?

1…………………….2…………………..……3………………..………4……………...5

Not At all *Very Much*

How easy would PALS-Math be for you to do on your own?

1…………………….2…………………..……3…………….………4……………...5

Not Easy At all *Very Easy*

How many minutes does math instruction take place in your classroom each week?

____