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Lloyd, Jason Duran

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Effects of Math Interventions on Elementary Students' Math Skills:
A Meta-Analysis

A Thesis submitted in partial satisfaction
of the requirements for the degree of

Master of Arts

in

Education

by

Jason D Lloyd

June 2013

Thesis Committee:
        Dr. Mike Vanderwood, Chairperson
        Dr. Cathleen Geraghty
        Dr. Gregory Palardy

The Thesis of Jason D Lloyd is approved:

<div align="right">Committee Chairperson</div>

University of California, Riverside

ABSTRACT OF THE THESIS

Effects of Math Interventions on Elementary Students' Math Skills:
A Meta-Analysis

by

Jason D Lloyd

Master of Arts, Graduate Program in Education
University of California, Riverside, June 2013
Dr. Mike Vanderwood, Chairperson

Over 20% of public school students are in need of additional math support. For this reason, it is crucial that schools utilize the most effective math interventions to help improve student outcomes. Meta-analytic procedures were conducted in order to evaluate the effectiveness of hierarchical math interventions used to improve math skills. Results suggested that math fluency interventions were more effective than math acquisition interventions in improving student basic math skills. Furthermore, generalization interventions were found to have a greater effect on word problem-solving skills compared to math fluency and math acquisition interventions. These results suggest that math fluency interventions are effective in improving basic math skills. However, generalization interventions are currently the most effective method when improving specific higher order math skills. Practical implications of these results are also discussed.

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Introduction

According to the National Assessment of Education Progress (NAEP, 2007), approximately 38% of United States fourth grade students were classified as having proficient math skills. By eighth grade, this proportion decreases to 34% (NAEP, 2011). Current statistics in the US have demonstrated a significant decrease in students receiving degrees within the STEM (science, technology, engineering, and math) fields due to a lack of sufficient math knowledge (NMAP, 2007). These statistics are troubling considering that math proficiency has been directly related to successful employment after completing high school and successful independent living later in life (Patton, Cronin, Bassett, & Koppel, 1997; Saffer, 1999). When a student is classified as having a math deficit, the most effective method to improve math skills is to implement a math intervention (Burns, 2002; Gickling, Shane, & Croskery, 1989). Unfortunately, current practices within schools frequently utilize interventions that have little positive effect (Burns, Codding, Boice, & Lukito, 2010). The emergence of evidence-based practice standards (Coalition of Evidence-Based Policy, 2002) within the schools has helped improve the quality of interventions being implemented in the schools by promoting use of interventions supported by high quality research.

Considering that an average of 20% of elementary school students are in need of additional support beyond the common instruction being received within the classroom (Burns, Appleton, & Stehouwer, 2005), it is important that schools focus on implementing interventions that are highly focused on evidence-based practices in order to be as effective as possible (Burns, VanDerHeyden, & Boice, 2008). Common practices

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within the schools utilize interventions focused on improving the aptitude or abilities of a student (Aptitude-by-Treatment Interaction; ATI; Cronbach, 1957). These interventions attempt to improve math performance through the improvement of cognitive processes (e.g., working memory). However, interventions focused on improving academic skills are more effective than interventions attempting to improving cognitive processes (Kavale & Forness, 2001). Intervention techniques developed upon the principles of the learning hierarchy (Haring & Eaton, 1978; Rivera & Bryant, 1992) are highly effective in improving math skills (e.g., Codding, Chan-Iannetta, Palmer, & Lukito, 2009; Dyson, Jordan, & Glutting, 2011; Menesses & Gresham, 2009). Initially, a student is slow and inaccurate as they complete a math task. As the student's skills progress, their rate of accuracy and speed when completing math tasks increases. It is after this point that a student is ready to apply their knowledge to help them solve a new math task. This process can be divided into four unique levels known as acquisition, fluency, generalization, and application. These four levels are crucial in the development of math proficiency (Rivera & Bryant, 1992).

Instructional Hierarchy Interventions

    One of the most common reasons that students are referred for assessment related to math disabilities is due to a difficulty with acquiring basic math skills (Shapiro, 1989). As students begin receiving instruction in math, they enter the acquisition stage of math performance. During this phase, the student is initially very slow to finish a math problem and is likely to make simple common mistakes (VanDerHeyden & Burns, 2008). In order to help students with math acquisition deficits, acquisition interventions were developed

in order to provide intensive interventions to students that lack basic math skills (Rivera & Bryant, 1992). As students' understanding of these strategies improves, we expect their problem solving skills to also improve and to see these strategies generalize across related tasks (Shapiro, 1989). Recent research (Burns et al., 2010; Codding et al., 2007) has found that acquisition interventions are most effective when students border on frustration level of math skills.

When a student has proceeded beyond the acquisition stage of math performance, he or she enters the proficiency stage. During this stage of math performance a student has the skills necessary to effectively perform a math task, but is slow in their execution (VanDerHeyden & Burns, 2008). In this stage, the goal of math performance is for students to gain computational fluency. Students exhibit computational fluency when they have the skills necessary to recall an answer to a math problem quickly rather than needing to perform the necessary mathematical procedures (Logan, Taylor, & Etherton, 1996). Having fluency with number combinations (e.g., $6 + 5 = 11$; $8 - 3 = 5$) has been shown to give students a significant skill pertaining to procedural computation and word-problem performance (Fuchs, Fuchs, Compton, Powell, Seethaler, Capizzi, 2006). Computational fluency is an important goal for overall math understanding because students must be fluent with basic math skills in order to transfer basic math skills to more advanced math tasks (National Council of Teachers of Mathematics [NCTM], 2000). Past meta-analytic research evaluating the effectiveness of math interventions found math fluency interventions to have a moderate effect on math skills when students

had frustration level math skills (Burns et al, 2010). However, this study failed to address the effectiveness of small group math interventions.

As students progress, the skills necessary to transfer math skills into word problem-solving becomes crucial (Bransford & Schwartz, 1999). During the generalization stage of the learning hierarchy, students must transfer basic math skills into novel math tasks (Rivera & Bryant, 1992). Although students may have an understanding of a mathematical concept, they can struggle when a simple math problem is changed even slightly (Larkin, 1989). Past research has suggested that generalization can be achieved by being computationally fluent. However, educators typically improve generalization skills by teaching specific strategies (Poncy, Duhon, Lee, & Key, 2010). A strategy that could help improve these generalization skills is called schema-based instruction. Schemas are defined as categories under which similar math problems can be classified (Chi, Feltovich, & Glaser, 1981). Broadening schemas (or the category of a type of problem) will increase the probability that students will be better able to effectively navigate through a word problem that previously would have caused them to struggle (Fuchs, Fuchs, Craddock, Hollenbeck, Hamlett, & Schatschneider, 2008). Generalization is frequently a stage of math instruction that is neglected within research and math instruction (Poncy et al., 2010; Rivera & Bryant, 1992).

The goal of schema-broadening instruction is to help students maintain more successful and flexible problem solving (Fuchs, Seethaler et al., 2008). Schema-broadening instruction equips students with the skills necessary to better categorize novel word problems with types of problems that they have completed in the past (Fuchs,

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Powell, Seethaler, Cirino, Fletcher, Fuchs, & Hamlett, 2010). Past research has advocated for the use of math instruction to teach students problem contexts that are likely to occur in the "real-world (NMAP, 2008)." Schema-broadening instruction has shown to be a highly effective method that can give students skills necessary for these types of contexts such as a shopping list problem that involves the student finding items on the list and calculating costs (Fuchs, Fuchs, Finelli, Courey, & Hamlett, 2004). Furthermore, a recent literature review of schema-broadening interventions found very large effects on students' word problem-solving skills (Powell, 2007).

Purpose

Given the lack of research conducted in the area of hierarchical instruction for math interventions, the meta-analysis was conducted in order to synthesize the effects of hierarchical math interventions on computation skills as well as word problem-solving skills. The purpose of the meta-analysis is to evaluate the effects of group design math interventions developed on the stages of the learning hierarchy. A lack of research in the area of math generalization skills has been a noted problem (Poncy et al., 2010). To date there has been little research comparing the effects of hierarchical math interventions on word problem-solving skills. The present meta-analysis will contribute to the evidence-base of generalization math interventions. This is also the first meta-analysis synthesizing the results of hierarchical early numeracy interventions. It is important for this synthesis due to the importance early numeracy skills in student developmental math skills (Gickling et al., 1989).

The meta-analysis was guided by the following research questions: (1) To what extent do math acquisition interventions improve basic math skills as opposed to math fluency interventions; (2) To what extent do generalization interventions improve word problem-solving skills as opposed to other hierarchical instruction interventions; (3) To what extent does a difference exist between grade level math interventions?

Methods

Sample of Studies

Data collection was conducted using the PsychINFO and ERIC electronic databases. Key terms for the meta-analysis were collected based on research conducted in the areas of math instruction (NMAP, 2008), math fluency and acquisition interventions (Burns et al., 2010), and schema-based math interventions (Powell, 2011). A search was conducted for articles using the terms "*math intervention*" (880), "*number identification*" and "*intervention*" (13), "*counting*" and "*intervention*" (18), "*number sense*" and "*intervention*" (257), "*digits correct*" and "*intervention*" (15), "*addition*" and "*intervention*" (68), "*subtraction*" and "*intervention*" (15), "*multiplication*" and "*intervention*" (20), "*division*" and "*intervention*" (31), "*acquisition*" and "*intervention*" (20), "*fluency*" and "*intervention*" (25), "*word problems*" and "*intervention*" (35), "*schema*" and "*intervention*" and "*math*" (918), and "*story problems*" (503). Through this search, a total of 2,818 articles were identified for possible inclusion for the current meta-analysis.

Selection Criteria

Identified articles were analyzed based on the following criteria:

1. Study implemented a math intervention aimed at improving mathematics skills of students between Kindergarten and fifth grade.

2. Published in a peer reviewed academic journal since 1982.

3. Intervention was conducted using a group design within the schools.

4. The study included use of a control group and a treatment condition.

5. Group comparisons were used to analyze effectiveness of the intervention.

6. A pre-test/post-test design was utilized to evaluate effectiveness of the intervention.

7. Intervention was either administered to a single grade level or provided relevant data for all grades included in the study.

8. The study included enough quantitative data that could be used to calculate an effect size.

9. Enough detail was provided to conclude whether a math fluency intervention, math acquisition, or a generalization intervention was used during the study.

10. The study was written in English.

After narrowing the population of articles to only studies meeting the previously mentioned criteria, the reference list of identified articles was reviewed for possible articles that could be included in further analysis as recommended by previous meta-analytic research (Cooper, 1998). The end result produced 16 studies that were identified for inclusion in the current meta-analysis.

Moderators

Variables included in analysis included (a) the intervention used during the study, (b) the dependent measure that was used to measure growth, and (c) the type of

intervention strategies utilized. Table 1 provides a reference for study variables after being categorized.

The interventions administered in the studies were categorized based upon the type of intervention and the stage of learning that the intervention was aimed at improving. Three categories were found when examining the current sample of studies. Interventions identified for inclusion were focused on improving a student's math acquisition skills, computational fluency, or utilizing the strategies of schema-broadening instruction in order to improve word problem-solving skills.

Studies were also coded based on the intervention that was used to help improve student academic outcomes. For the studies included within the meta-analysis, 24 different intervention strategies were utilized. A list of these interventions has been included in Table 1. Eight of the studies included in the current analysis implemented multiple math interventions. Eight of the included studies implemented strategies related to schema-broadening instruction (Fuchs, Fuchs et al., 2008). One study (Codding et al., 2009) implemented a class-wide form of Cover-Copy-Compare (Skinner, McLaughlin, & Logan, 1997). Two included studies utilized the math intervention Peer Assisted Learning Strategies (PALS; Fuchs, Fuchs, Phillips, Hamlett, & Karns, 1995). One study (Ginsburg-Block & Fantuzzo, 1998) implemented similar strategies that taught students problem solving strategies and peer collaboration. Two studies implemented interventions that were developed to help improve number sense skills of early elementary age students (Number Sense; Jordan, Glutting, Dyson, Hassinger-Das, & Irwin, 2012). The remaining study (Tournaki, 2003) implemented both an acquisition

intervention (e.g., teaching math strategies to improve math skills) and a math fluency intervention (e.g., drill and practice of math skills).

Analyses of Effect Sizes

Effect size estimates were conducted for each dependent variable that was included in the sample studies. The effect size estimate chosen for the current meta-analysis was based on Glass' (1976) research on statistical power analysis. When choosing the specific formula that would be used to calculate the effect size estimates for the current meta-analysis, Glass' Standardized Mean Difference (Hedges g; Hedges, 1981) was selected. This formula is suggested for use when effect sizes must be conducted on several different types of tests. Effect size calculation utilized the following formula:

$$ES_{sm} = \frac{\overline{X}_{G1} - \overline{X}_{G2}}{s_p}$$

where $\overline{X}_{G1}$ is the sample mean of the of the treatment group on the dependent variable within each study at the time of post-test, $\overline{X}_{G2}$ is the sample mean of the control group at the time of post-testing, and s_p is the standard deviation pooled across testing.

The resulting effect size estimates were then evaluated using the criterion that was established by Cohen (1988), where interventions with an effect size greater than 0.80 are considered to have a large effect on student math skills. Effect sizes of 0.50 are considered to have caused a moderate effect in academic skills, while effect sizes lower than 0.20 have shown little effect in student math skills.

One criticism of meta-analyses is that ineffective interventions are averaged with effective interventions. A method of controlling for this problem is by using a weighted effect size (Rosenthal & DiMatteo, 2001). This meta-analysis implemented weighting procedures as suggested by Hedges (1981) in order to present the most appropriate results. Furthermore, this meta-analysis will include research focused on implementing evidence-based practices. In order to ensure that the interventions qualifying for analysis are truly effective, only studies that included a control group in the intervention were selected as stated by National Research Council (2002). In order to determine statistical significance of a sample of studies, further calculations must be conducted in order to find the weighted effect sizes relative to the sample size found in each study. With the previous effect size information, a mean effect size, z-test, and confidence interval can then be calculated as directed by Lipsey & Wilson (2001). These calculations are as follows:

$$ES'_{sm} = \left(1 - \frac{3}{4\text{N-1}}\right) \times ES_{sm}$$

$$SE_{sm} = \sqrt{\frac{n_{G1} + n_{G2}}{n_{G1} \times n_{G2}} + \frac{(ES'_{sm})^2}{2(n_{G1} + n_{G2})}}$$

$$w_{sm} = \frac{1}{SE^2_{sm}}$$

$$\overline{ES} = \frac{\Sigma(w_{sm} \times ES_{sm})}{\Sigma w_{sm}}$$

$$SE_{\overline{ES}} = \sqrt{\frac{1}{\Sigma w_{sm}}}$$

$$z = \frac{\overline{ES}}{SE_{\overline{ES}}}$$

If this observed *z*-score exceeds the critical *z*-value of 1.96, it can be concluded that the mean effect size of the sample of studies is statistically significant. For the current meta-analysis, a Cochran's Q test for homogeneity of variance (Cooper, 1998) was also conducted in order to determine whether the observed data is practically significant with the following equation:

$$Q = \sum(w \times ES^2) - \frac{(\sum w_{sm} \times ES_{sm})^2}{\sum w_{sm}}$$

If the resulting *Q*-value does not exceed the .05 critical value relative to the degrees of freedom of the sample size then the assumption of homogeneity of variance can be satisfied meaning that the variance of the current sample of effect sizes is not significantly greater than is expected from sampling error alone.

In order to better understand the effects of failing to satisfy the assumption of homogeneity of variance, more calculations were conducted to quantify the impact of heterogeneity:

$$I^2 = \frac{Q - df}{Q}$$

While Cochran's Q is a useful method of testing for heterogeneity, the statistic overestimates the level of heterogeneity between studies (Higgins & Thompson, 2002). In order to give a more appropriate idea of the impact of heterogeneity existing between studies, Higgins and Thompson (2002) developed the I^2 statistic to gauge the impact of heterogeneity. Furthermore, a One-Way ANOVA with a Tukey's posthoc comparison

was conducted to determine whether the mean effect sizes were significantly different based upon the grade level or type of intervention.

<p style="text-align:center">Results</p>

Statistical procedures discussed previously were used to evaluate the differences in the effects of math acquisition and math fluency interventions on basic math skills. Math fluency interventions were found to have a moderate to large effect size on basic math skills (ES = .71). Math acquisition interventions (ES = .48) were found to only have a moderate sized effect on basic math skills. Both math intervention techniques showed significant effects in basic math skills. These results can be viewed in Table 2. While math fluency interventions were more effective in improving basic math skills, fluency interventions were not significantly more effective than math acquisition interventions ($p > .05$).

The second question the meta-analysis answered whether there was a difference in the effect sizes of generalization interventions as compared to interventions developed on the earlier stages of the learning hierarchy (math acquisition and math fluency). Of the categories of math interventions that included strategies related to the learning hierarchy, both math acquisition (ES = .48) or math fluency (ES = .71) intervention methods showed a moderate effect in math skills, while generalization interventions resulted in a very large effect (ES = 1.34). All intervention techniques were found to result in a statistically significant change in math skills. When conducting a Cochran's Q test of homogeneity of variance, it was found that math fluency and math generalization interventions violated this assumption. However, after calculating an I^2 statistic, it was

revealed that no variance between math fluency interventions was accounted for by heterogeneity. Furthermore, the I^2 statistic calculated for generalization interventions found that 27% of variance between these studies was accounted for by heterogeneity. It is suggested that this proportion resulted in only minimal concern when making practical implications. Schema-broadening interventions resulted in a significantly greater effect on math skills when compared to math acquisition interventions ($p < .01$).

The third research question was aimed at evaluating the differences in effects of grade level math interventions. Interventions implemented in studies attempting to improve kindergarten math skills showed a significant, moderate effect (ES = .41) with a wide variability in the size of effects found [.09, .69]. Of all the studies that were included in the meta-analysis, interventions aimed at improving first-grade math skills showed the lowest degree of effect (ES = .12). First grade math interventions resulted in a small effect in student math skills [-.45, .70]. Second grade math interventions resulted in a very large effect size (ES = 1.31). These effects were the largest found of all grade level math interventions. While not as large as the effects of second grade math interventions, third grade math interventions still resulted in a highly significant effect in math skills (ES = .88).   Fourth grade math interventions showed a moderate effect in student math skills (ES = .53). Analysis of third grade math interventions showed a significant violation of the assumption of homogeneity of variance. However, an analysis of the I^2 statistic shows that only 40% of the variance can be attributed to heterogeneity. Complete lists of these results are included in Table 3. No significant differences were found between the grade-level math interventions.

Discussion

Math Fluency versus Math Acquisition Interventions

The first question that the meta-analysis sought to answer was to determine the extent of the difference in the effectiveness of math fluency interventions and math acquisition interventions. The study found similar effects for both types of math interventions. Math fluency interventions showed a larger effect (ES = .71) on student math skills as compared to math acquisition interventions (ES = .56). However, these results are not significant different from each other. Overall, these results are inconsistent with the results found in Burns and colleagues (2010). Burns and colleagues (2010) found that math acquisition interventions were more effective than math fluency interventions. However, results found by Burns and colleagues (2010) found that math fluency interventions were more effective when students had instructional level math skills. Only one study included in the present meta-analysis (Burns et al., 2012) utilized screening procedures to identify students for intervention. Burns and colleagues (2012) found small-to-moderate effects in improving math skills with a math fluency intervention (ES = .42). These results are consistent with past meta-analyses evaluating the effects of math fluency interventions (Burns et al., 2012; Codding, Burns, & Lukito, 2011). However, no other studies included in the analysis utilized screening procedures to identify students for intervention. Thus, it was not possible to determine the skill level of the student samples included in this meta-analysis. Math acquisition interventions were found to have a moderate effect on math skills [.48, .64]. These results were found to be consistent with the results of Burns and colleagues' (2010) meta-analysis when a math acquisition

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intervention was implemented to students with instructional level math skills. While both intervention types were found to significantly improve math skills, the effect sizes corresponding to math acquisition interventions failed to satisfy the assumption of homogeneity of variance. This indicates that the variance is far too large to make practical implications about the mean effect size of math acquisition interventions (Higgins & Thompson, 2002).

Generalization versus Math Fluency and Math Acquisition Interventions

The second question that the research attempted to answer was whether there was a difference between the effectiveness of generalization interventions and interventions intended to improve word problem-solving skills through the transfer of improved math acquisition or math fluency skills. Jitendra and colleagues (1998) implemented a math acquisition intervention in order to improve word problem-solving skills through the generalization of basic math skills to word problem-solving. Past research has suggested that these transfer skills, generalizing basic math skills to complete more difficult math tasks, are highly important in students as they progress through math instruction, but are lacking in students with severe deficits in math skills (Salomon & Perkins, 1989). Thus, the results of the meta-analysis suggest that generalization interventions are more effective in improving specific math skills than interventions improving these skills through a transfer of improved basic math skills.

The magnitude of the effect of generalization interventions on math skills was found to be very large (ES = 1.34). The majority of effect sizes of generalization interventions suggest that most of these interventions are highly effective when used to

improve math word problem-solving skills [1.84, 2.44]. These results are consistent with a recent literature review evaluating the effectiveness of schema-broadening interventions (Powell, 2007). When compared to the effects of math acquisition interventions (ES = .48) and math fluency interventions (ES = .71), generalization interventions (ES = 1.34) showed a much larger effect in math skills. The current results suggest that instruction explicitly aimed at improving word problem-solving skills has a much greater effect than traditional math interventions seeking to show transfer effects from basic math skills to word problem-solving skills. These results reinforce past research suggesting that teaching specific strategies is more effective than teaching basic math skills in attempts of these skills to generalize to more complicated math problems (Poncy et al., 2010). Furthermore, these results support the use of using thematic units to improve the generalization of math skills as suggested by Rivera and Bryant (1992).

Implications

It is important for schools to focus on choosing the most effective interventions to improve student outcomes. The results of the meta-analysis suggest that math fluency interventions are more effective than math acquisition interventions in improving basic math skills. This is contrary to results of past research comparing these two intervention techniques. Burns and colleagues (2010) found math acquisition interventions to be more effective in improving basic math skills than math fluency interventions. One possible reason for these conflicting results could be the instructional match of the intervention. Math acquisition interventions are most effective when implemented to students with frustration level math skills, while math fluency interventions are most appropriate when

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implemented to students with instructional level math skills (Burns et al., 2010). Due to only one study utilizing universal screening procedures to identify students for intervention (Burns et al., 2012), it was not possible to determine the skill level of the student sample included in the present analysis.

The meta-analysis found that kindergarten, second grade, and third grade level math interventions resulted in significant effects in math skills. The most significant of these results were within the second grade math interventions. However, the largest effects were seen in the third grade math interventions. Kindergarten math interventions were found to have a statically significant effect on early numeracy math skills although these interventions only showed a moderate effect in math skills. These results reinforce the practice of early identification for remediating math deficits.

The results of the present research suggest that early numeracy interventions result in significant positive growth in math skills. However, only one article (Fuchs et al., 2002) was included in the analysis that implemented a first grade math intervention and the results were non-significant. A possible reason for this result is due to the inappropriate nature of the outcome measure used to measure growth. Fuchs and colleagues (2002) measured growth using the Stanford Achievement Test, 9th Edition (SAT-9; Gardner, Rudman, Karlsen, & Merwin, 1987). The results of this assessment were reported as two different question groupings (i.e., questions that were aligned with PALS curriculum, and questions that were not aligned with PALS curriculum). The modification to the assessment decreases the reliability of the measure (AERA Standards, 1999) which possibly contributes to the non-significant results of the intervention.

During the data collection of this meta-analysis, very few studies were found implementing an early numeracy math intervention. It is during these years when early intervention is most important since development of a learning disability at an early age can persist throughout a student's education (Cawley & Miller, 1989; Rivera-Batiz, 1992). Furthermore, kindergarten math skills have been shown to be a significant predictor of later academic achievement across contents (Duncan et al., 2007).

Limitations

The greatest limitation that was faced while conducting the current meta-analysis was the lack of high quality studies evaluating the effectiveness of math interventions. While there is no set standard for the number of studies needed in a meta-analysis, the general consensus is that more studies will result in more powerful results (Cooper, 1998; Higgins & Thompson, 2002; Lipsey & Wilson, 2001). However, this lack of research is not limited to only math intervention research. An extreme discrepancy exists within mathematics research as a whole which could be as great as 15:1 when compared to the number of reading articles to the number of math research articles (Gersten, Clarke, & Mazzocco, 2007). Fortunately, an increase in interest related to math instruction can be witnessed through recent literature (Clarke, Gersten, & Newman-Gonchar, 2010).

Several of the studies included evaluating schema-broadening instruction interventions utilized outcome measures developed by the primary investigator (e.g., Fuchs, Seethaler et al, 2008; Fuchs, Powell et al, 2008). It could be considered a limitation that a larger variety of outcome measures has not been used to evaluate the effects of schema-broadening interventions.

A limitation of the study was the violation of assumption within the data. While many statistically significant results were found, caution should be taken when interpreting results where the assumption of homogeneity of variance had been violated. Also, consideration should be given to the magnitude of the I^2 statistic denoting the level of caution that should be associated with each mean effect size. Based on the recommendations of Higgins and Thompson (2002), moderate caution will be taken when evaluating these results.

Another limitation found in the study was the lack of interrater reliability. Interrater reliability within meta-analysis refers to having an independent member confirm that a portion of qualifying studies do in fact qualify for inclusion within the meta-analysis. Due to the nature of the thesis project, the current meta-analysis was conducted independently. Thus, there was no chance to collect interrater reliability data. However, many academic meta-analyses (e.g., Fan & Chen, 2001; Jeynes, 2003; Vernon & Blake, 1993) do not calculate interrater reliability. In fact, Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Liberati et al., 2009) does not included interrater reliability as a standard necessary for conducting a meta-analysis.

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Table 1

Description of Included Studies by Sample Size, Dependent Variable, Type of Intervention, and Grade

Study	N	k	Grade	Intervention	Dependent
Burns et al., 2012	471	2	3rd, 4th	Math Facts in a Flash	Star Math
Codding et al., 2009	80	2	3rd	Copy, Cover, Compare	GOM, CBM
Codding et al., 2011	66	4	K	K-PALS Math	NI, MN, QD, TEMA-3
Dyson et al., 2011	121	2	K	Number Sense	NSB, WJ-III ACH Math
Fuchs et al., 2002	345	2	1st	PALS Math	SAT-9 (A + U)
Fuchs Fuchs et al., 2003	565	9	3rd	Solution, Part Solution +, Full Solution +	Immediate, Near, Far
Fuchs, Fuchs Finelli et al., 2004	303	8	3rd	SBTI, Expanded SBTI	Multiple Transfer Tasks
Fuchs, Fuchs, Prentice et al., 2004	367	6	3rd	SBI, SBI with Sorting	Immediate, Near, Far
Fuchs et al., 2006	445	12	3rd	SBI, SBI – RL	Immediate, Near, Far

Note. k = Number of effects each study produced by study. K-PALS = Kindergarten – Peer Assisted Learning Strategies; PALS = Peer Assisted Learning Strategies; GOM = General Outcome Measure; SBI = Schema-broadening Instruction; SBI – RL = Schema-broadening Instruction – Real Life; CBM = Curriculum-based Measure; NI = Number Identification (Lembke & Foegen, 2009); MN = Missing Number (Lembke & Foegen, 2009); QD = Quantity Discrimination (Lembke & Foegen, 2009); TEMA-3 = Test of Early Mathematics Ability, 3rd Edition (Ginsburg & Baroody, 2003), NSB = Number Sense Brief (Jordan, Glutting, Ramineni, & Watkins, 2010); WJ-III ACH Math = Woodcock Johnson, 3rd Edition Math Subtests (Woodcock, McGrew, & Mather, 2007); SAT – 9 = Stanford Achievement Test, 9th Edition (Gardner, Rudman, Karlsen, & Merwin, 1987); A + U = Question from SAT – 9 that are aligned and unaligned with PALS (Fuchs et al., 2002)

Table 1 (Cont.)

Description of Included Studies by Sample Size, Dependent Variable, Type of Intervention, and Grade

Study	N	k	Grade	Intervention	Dependent
Fuchs, Fuchs et al., 2008	407	6	4th	Hot Math SBI	Immediate, Near, Far
Fuchs, Seethaler et al., 2008	35	10	3rd	Pirate Math SBI	AF, SF, DD, DDS, WRAT-3 Arith, AE, JSP, PWP, KM, ITBS
Fuchs, Powell et al., 2010	170	14	3rd	Pirate Math, Tutoring	NC, PC, FX, NS, VSP, KM
Fuchs, Zumeta et al., 2010	19	8	2nd	SBI	VSP
Ginsburg-Block & Fantuzzo, 1998	156	6	3rd	PS, PC, PLUS	CBCT, CBWPT
Jordan et al., 2012	132	2	K	Number Sense	WJ-III ACH Form C
Tournaki, 2003	42	2	2nd	Strategy, D/P	Transfer Task

Note. k = Number of effects each study produced by study. SBI = Schema-broadening Instruction; PS = Peer Support (Ginsburg-Block & Fantuzzo, 1998); PC = Peer Collaboration (Ginsburg-Block & Fantuzzo, 1998); AF = Addition Fact Fluency (Fuchs, Hamlett, & Powell, 2003); SF = Subtraction Fact Fluency (Fuchs, Hamlett et al., 2003); DD = Double-Digit Addition Test (Fuchs, Hamlett et al., 2003); DDS = Double-Digit Subtraction Test (Fuchs, Hamlett et al., 2003); WRAT – 3 Arith = Wide Range Achievement Test, 3rd Edition (Wilkinson, 1993); AE = Algebraic Equations (Fuchs & Seethaler, 2005); JSP = Jordan Story Problems (Jordan & Hanich, 2000); PWPT = Peabody Word Problems Test (Fuchs, Seethaler, & Hamlett, 2005); KM = KeyMath – Revised (Connolly, 1998); ITBS = Iowa Test of Basic Skills (Hoover, Hieronymous, Dunbar, & Frisbie, 1993); NC = Number Combination Subtests (Fuchs, Powell, & Hamlett, 2003); PC = Procedural Calculations (Fuchs, Hamlett et al., 2003); FX = Find X (Fuchs & Seethaler, 2008); NS = Number Sentences (Fuchs & Seethaler, 2008); VSP = Vanderbilt Story Problems (Fuchs & Seethaler, 2008); CBCT = Curriculum-based Computation Test (Tucker, 1985); CBWPT = Curriculum-based Word Problem Test (Tucker, 1985); WJ-III ACH 3rd Edition Form C Brief (Woodcock, McGrew, & Mather, 2007); D/P = Drill & Practice

Table 2

Effect Size Estimates by Intervention

Grade	N	k	Median ES	Min ES	Max ES	Mean ES	95% CI	Q	I^2
Acquisition	8	23	.44	.05	1.49	.48****[a]	[.27, .69]	13.13	.00
Fluency	4	6	.50	.23	1.31	.71***	[.29, 1.12]	14.57*	.00
Generalization	6	53	1.30	.34	10.29	1.34****[a]	[1.05, 1.62]	91.61***	.27

Note. N = Number of studies where the type of interventions were conducted. Some studies implemented multiple types of interventions. k = Number of effects each study produced by the intervention method that was used. * = indicates statistical significance at the .05 level. ** = indicates statistical significance at the .01 level. *** = indicates statistical significance at the .001 level. **** = indicates statistical significance at the .0001 level. Superscripts indicate values that are significantly different.

Table 3

Effect Size Estimates by Grades of Student Participants

Grade	N	k	Median ES	Min ES	Max ES	Mean ES	95% CI	Q	I^2
Kindergarten	3	8	.38	.06	.78	.39*	[.09, .69]	1.69	.00
1st Grade	1	2	.10	.05	.15	.12	[-.45, .70]	.02	.00
2nd Grade	2	10	1.00	.58	2.00	1.31****	[.84, 1.80]	1.02	.00
3rd Grade	9	68	.95	.17	10.29	.88***	[1.33, 1.49]	110.98***	.40
4th Grade	2	7	.96	.33	1.14	.53	[-.10, 1.16]	.61	.00

Note. N = Number of studies. k = Number of effects each study produced by grade of the participant. * = indicates statistical significance at the .05 level. ** = indicates statistical significance at the .01 level. *** = indicates statistical significance at the .001 level. **** = indicates statistical significance at the .0001 level.