Published in final edited form as:

Elem Sch J. 2015 December ; 116(2): 242–246. doi:10.1086/683986.

Reading Stories to Learn Math: Mathematics Vocabulary Instruction for Children with Early Numeracy Difficulties

Brenna Hassinger-Das^a, Nancy C. Jordan^a, and Nancy Dyson^a

^aSchool of Education, University of Delaware, Newark, Delaware, 19716, United States of America

Abstract

The present study involved examining whether a storybook reading intervention targeting mathematics vocabulary, such as “equal,” “more,” and “less,” and associated number concepts would increase at-risk children’s vocabulary knowledge and number competencies. Children with early numeracy difficulties (N = 124) were recruited from kindergarten classes in four schools. Participants were randomly assigned to one of three groups: a storybook number competencies (SNC) intervention, a number sense intervention, or a business-as-usual control. Interventions were carried out in groups of four children over 8 weeks (24 thirty-minute sessions). Findings demonstrated that the SNC intervention group outperformed the other groups on measures of mathematics vocabulary, both in terms of words that were closely aligned to the intervention and those that were not. There was no effect of the SNC intervention, however, on general mathematics measures, suggesting a need to provide the mathematics vocabulary work along with more intensive instruction in number concepts.

In the absence of effective, evidenced-based instruction, children who come to school with low mathematics and reading skills may never catch up to their normally achieving peers. (Anderson & Nagy, 1992; Hart & Risley, 1995). In addition to having trouble with number, children with early numeracy difficulties also have difficulties understanding mathematical language (Kleemans et al., 2011; Schleppegrell, 2010). However, educational interventions in pre-K and kindergarten show promise for helping all children develop the necessary skills for learning general vocabulary (Marulis & Neuman, 2010) and number knowledge (Dyson, Jordan, & Glutting, 2013; Jordan, Glutting, Dyson, Hassinger-Das, & Irwin, 2012) in kindergarten and beyond.

The present study examined an intervention, referred to as the Storybook Number Competencies (SNC) intervention, which targeted specific words for describing mathematical concepts as a way to increase both children’s vocabulary understanding and their ability to describe and manipulate number concepts (Bracken, 2006b; Halberda, Taing, & Lidz, 2008; Purpura, Hume, Sims, & Lonigan, 2011; Vanderlinde, 1964). Many children’s trade books provide ample opportunities to introduce rich mathematics vocabulary (Beck, McKeown, & Kucan, 2002), and previous research suggests that

storybook interventions lead to substantial gains in either vocabulary understanding (Beck & McKeown, 2001a; Biemiller & Boote, 2006; Coyne, Simmons, Kame'enui, & Stoolmiller, 2004; Han, Moore, Vukelich, & Buell, 2010; Justice, Meier, & Walpole, 2005; Roskos & Burnstein, 2011; Wasik & Bond, 2001) or early mathematical knowledge (e.g., the count sequence, number combinations, and number comparisons) (Hong, 1996; Jennings, Jennings, Richey, & Dixon-Krauss, 1992; Young-Loveridge, 2004).

A review of the literature reveals that to date no randomized studies that feature mathematics vocabulary in order to systematically increase both the specific mathematics language and mathematical knowledge of children with early numeracy difficulties have been conducted. Several popular books provide anecdotal evidence to encourage classroom teachers to integrate storybooks and mathematics, but these books do not provide empirical evidence through randomized trials to determine the success of combining storybook reading and mathematics to affect mathematics vocabulary or mathematics achievement. The present study investigated whether providing help with number concepts in a language-rich context improves learning outcomes for kindergarten students with demonstrated low number knowledge.

Relationships among Mathematical Representations

When children's previous ideas about mathematical concepts are connected with new information, they are more likely to retain and transfer the information (Van De Walle, 2007). Mathematical information comes in various internal and external forms, known as representations (Pape & Tchoshanov, 2001). Internal representations consist of individuals' experientially developed mathematical ideas, while external representations include words, equations, numerals, and various other ways to depict mathematical concepts (Pape & Tchoshanov, 2001). By connecting related representations, such as five cookies and the numeral 5, children are able to extend their mathematical knowledge to a variety of situations (Carpenter, Hiebert, & Moser, 1983; Gersten, Jordan, & Flojo, 2005).

Representations can be either non-symbolic (e.g., a group of 5 items) or symbolic (e.g., the numeral 5, the word "five"). From infancy, children can make distinctions between non-symbolic groupings of different quantities (Feigenson, Dehaene, & Spelke, 2004). Children's ability to connect symbolic and non-symbolic representations begins during the preschool years with exposure to mathematics talk (Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006) and written number symbols.

Although mathematics is often associated with numbers and arithmetic symbols instead of vocabulary and language, an understanding of various symbolic representations—including verbal representations—is an integral part of mathematical knowledge (Skemp, 1987). By learning the words for numbers and mathematical concepts, children are able to advance their mathematics thought processes beyond non-verbal representations (Mix, Huttenlocher, & Levine, 2002). Mathematics words help children discover commonalities among items by learning ways to describe their attributes, such as number and size (Sandhofer & Smith, 1999; Waxman & Markow, 1995). For instance, understanding and appropriately using the

words “bigger” and “smaller” helps children explain the relationship between two numbers: 7 is bigger than 5, while 5 is smaller than 7.

Case and colleagues (e.g., Case et al., 1996; Case, 1998; Moss & Case, 1999) highlighted the importance of including multiple forms of mathematical representations in instruction. As children develop their quantitative thinking, they begin to fuse together different mathematics conceptual maps. For instance, children learn to combine their understandings of “before” and “after” on a number line to answer questions regarding numbers that come before or after other numbers (Case, 1998). Instruction serves the function of scaffolding children’s ability to build and refine their mathematics conceptual structures (Moss & Case, 1999).

By providing a framework for representing and describing numerical relationships, mathematics vocabulary highlights the “big ideas” in mathematics (Baroody, Cibulskis, Lai, & Li, 2004). The big ideas in mathematics are “overarching concepts that connect multiple concepts, procedures, or problems within or even across domains or topics, and are integral to achieving a deep understanding of both concepts and procedures” (Baroody, Feil, & Johnson, 2007, p. 125).

The *Common Core State Standards in Mathematics – Kindergarten* (CCSSM; Common Core State Standards Initiative, 2010) advocate the use of a variety of models for the purpose of performing operations and solving problems. Kindergartners should be able to orally count a number of objects, name the quantity, and write the numeral for quantities up to 20. Also, kindergarten children should be able to, “represent addition and subtraction with objects, fingers, mental images, drawings, sounds (e.g., claps), acting out situations, verbal explanations, expressions, or equations.” (Common Core State Standards Initiative, 2010, p. 11) The connections between modeling, counting, and problem solving are critical at this foundational stage.

Development of Number Sense

Several related number competencies, referred to as number sense, significantly affect later mathematics outcomes (Jordan et al., 2006; Jordan et al., 2010a). Longitudinal research has demonstrated that that kindergarten number sense is highly predictive of mathematics problem solving through third grade (Jordan, Kaplan, Ramineni, & Locuniak, 2009; Jordan et al., 2010a) and middle school (Duncan et al., 2007), even after controlling for age, reading skills, and cognitive factors. Number sense encompasses the three core areas of counting, number relations, and number operations (Cross, Woods, & Schweingruber, 2009; Jordan et al., 2006; Malofeeva et al., 2004; National Research Council, 2009).

Symbolic number sense develops dramatically during the preschool years (Clements & Sarama, 2007). Children learn to recognize small quantities and count larger sets. As they learn the count sequence and the associated quantities, they begin to form a mental number list which allows them to then compare numerals. In addition to number words, words such as “before,” “after,” “bigger,” “smaller,” “closer to,” “add,” and “subtract” help children explain and describe numerical relationships and operations (Jordan, Glutting, Ramineni, & Watkins, 2010b). Research has shown that teachers’ use of mathematics talk has a positive

effect on children's mathematics growth (Klibanoff et al., 2006). Children may know or have heard these mathematics words in non-mathematical contexts, so it is crucial for them to be exposed to the mathematical meanings of these words and concepts (Lansdell, 1999).

Understanding vocabulary words in mathematical contexts allows children to work with number in ways that they previously could not (Gelman & Butterworth, 2005). For example, when children learn that the words "more" and "less" can be used to describe number, they have a way to verbally explain the differences between a box of 20 crayons and a box of 10 crayons. The use of storybooks that highlight mathematics vocabulary within in a number sense instructional context might help children "mathematize" or understand everyday situations in mathematical terms (National Research Council, 2009).

Effectiveness of Storybook Interventions for Building General Vocabulary

Storybook interventions have been shown to produce significant gains in vocabulary learning. Several studies have attempted to augment the vocabulary skills of children with low initial word knowledge through a combination of guided discovery learning (e.g., dialogic reading and guided play) and direct word instruction (Biemiller & Boote, 2006; Coyne et al., 2004; Coyne, et al., 2007; Han et al., 2010; Justice et al. 2005; Roskos & Burnstein, 2011; Wasik & Bond, 2001). The concept of guided discovery learning is closely related to the process of scaffolding—which includes structured adult support during the learning process (Putambekar & Hubscher, 2005). Both techniques use ongoing feedback during instruction to assess the educational needs of students (Clark, 2009; Putambekar & Hubscher, 2005). Dialogic reading encourages students to form their own ideas about new vocabulary words and then to apply their knowledge of those words to novel contexts (Whitehurst et al., 1988). During dialogic reading, children might be asked to explain stories in their own words, answer probing questions, and engage with the illustrations in the story all while receiving ongoing teacher assistance (Whitehurst et al., 1988). Similarly, guided play taps into children's natural curiosity about a topic and uses adult support to help guide children's discovery of the goals of the curriculum (Hirsh-Pasek, Golinkoff, Singer, & Berk, 2009).

Explicit instruction also is effective for generating vocabulary growth. Explicit instruction involves the teacher explaining the exact meaning of concepts and procedures (Kirschner, Sweller, & Clark, 2006). During vocabulary instruction, the teacher explicitly defines the target vocabulary words (Engelmann & Osborn, 1999). Prior meta-analyses of storybook reading interventions (Marulis & Neuman, 2010; Mol, Bus, & de Jong, 2009) demonstrate that storybook reading can foster word learning when explicit definitions are provided.

The combination instructional approach incorporates direct instruction of word definitions, instructional scaffolding, structured feedback, and guided play (Coyne et al., 2006; Han et al., 2010). The combination approach draws on several key principles of vocabulary learning including: 1) making word learning interesting to children, 2) relying on interactive and responsive contexts, 3) focusing on the meaning of vocabulary words in significant contexts, and 4) presenting clear definitions of vocabulary words (Harris et al., 2010). Studies show that children who received the combination guided discovery and explicit word meaning

approach made larger vocabulary gains than children who received only discovery learning or explicit instruction (Biemiller & Boote, 2006; Coyne et al., 2004; Coyne, et al., 2007; Justice et al. 2005; Wasik & Bond, 2001).

Effectiveness of Storybook Interventions for Improving Mathematics

Outcomes

Although several studies have examined the effectiveness of storybooks for boosting vocabulary, only one (Jennings et al., 1992) has investigated the effect of using storybooks to address both vocabulary and number knowledge, although this study has methodological shortcomings. Two other studies have examined the effectiveness of storybook reading for boosting early math skills (e.g., Hong, 1996; Young-Loveridge, 2004).

In a study of four U.S. kindergarten classrooms, Jennings and colleagues (1992) determined that children's scores on the *Test of Early Mathematical Ability* (TEMA; Ginsburg & Baroody, 1983) significantly improved from pre- to posttest in comparison to the business-as-usual control classrooms as a result of five months of incorporating general storybooks alongside the regular mathematics curriculum during whole-class instruction. However, effect size was not reported, making it difficult to determine the practical value of the differences. The children in the experimental group were read storybooks and completed mathematical activities related to the stories. Children in the experimental group did not make significant gains on the more general *Metropolitan Readiness Test* (MRT; Nurss & McGaurvan, 1986). Children were also observed during free play time to determine their use of mathematics vocabulary. Experimental group children used significantly more mathematics words than control group children. However, children's understanding of the meanings of mathematics vocabulary words was not systematically measured at any point during the study. Additionally, since random assignment was at the teacher- and not student-level, the results should be interpreted cautiously.

Young-Loveridge (2004) attempted to uncover the effectiveness of a program aimed at improving the numeracy of New Zealand kindergarten children using a small-group intervention that introduced number books and games. Children were randomly selected for the intervention group from those performing in the lowest two-thirds on a numeracy measure (Young-Loveridge, 2004). The instructor and pairs of children read mathematically themed storybooks, played games, and completed author-generated counting activities related to the content of the stories. The children in the business-as-usual control group received their regular mathematics curriculum. The intervention program produced a significant increase in children's numeracy knowledge at posttest ($d = 1.99, p < .01$) on an author-designed measure that was closely aligned to the content of the intervention. Despite a substantial reduction in the initial magnitude of the effect size, the effect of the intervention program held after 15 months at the final posttest ($d = .50, p < .05$). However, the researcher did not determine what aspects of the program produced the gains. Since there was only a business-as-usual whole class control, it is possible that just the extra amount of time spent on number activities in small groups resulted in better performance at posttest.

In a nine-week intervention study with kindergarten students randomly assigned to either an experimental or a control classroom in Korea, Hong (1996) found that children involved in the experimental condition—storybook reading and games—scored significantly better on author-designed classification, number combination, and shape tasks than the control group children who were read non-mathematical storybooks, but effect sizes were not reported. On a more general mathematics measure, the experimental group did not score significantly better than the control group. The children in Hong's study were predominately from high SES families, and the researcher speculated that the lack of significant difference between the two groups might have resulted from control group parents working with their children on take-home worksheets that included some of the content from the in-class lessons.

Looking across these studies, there is some evidence to suggest that a storybook intervention emphasizing number knowledge might improve kindergartners' performance in areas of early mathematics, but there is a need for further research. Only Jennings and colleagues (1992) addressed mathematics vocabulary in their study, but none of the studies included pretest and posttest mathematics vocabulary measures. Also, the studies contained methodological issues involving random assignment and control groups. Finally, only one of the studies featured children with early numeracy difficulties, a group needing additional, intensive mathematics instruction.

The present study builds on the previous research by testing the efficacy of a storybook number competencies intervention. Through the use of effective vocabulary instructional techniques, mathematics vocabulary becomes the specific focus of instruction, a feature not found in previous studies. By including general storybooks, children are exposed to the idea that mathematical concepts and words are not used only during math class. Due to ever-increasing demands for educators to make sure that students meet high educational standards, introducing ways to provide rich instruction through storybooks in multiple content areas gives teachers the ability to maximize their instructional time without taking away from children's exposure to key mathematics and language concepts.

The goal of the present study was to test the efficacy of the SNC intervention on kindergartners' mathematics vocabulary development as well as on their number competencies and general mathematics achievement. The majority of participants were children from high risk, low-income backgrounds, but all participants demonstrated early numeracy difficulties at kindergarten entry. Children were randomly assigned to the SNC group, a number sense intervention group without storybooks, and a business-as-usual control group. Using a pretest, immediate posttest, and delayed posttest design, we predicted that (1) children in the SNC intervention group would perform better than the children in the number sense and business-as-usual groups on a measure of mathematics vocabulary, and (2) there would be no significant differences between children in the number sense and the SNC intervention groups on mathematics outcomes due to the SNC intervention's inclusion of mathematics concepts.

Method

Sample

One hundred and twenty four children from 17 kindergarten classes in four schools in the same school district in the Mid-Atlantic region of the United States participated. Three of the schools served children from predominately low-income, minority families, and one school served both middle- and low-income families. Informed consent letters were sent home with every kindergartner. All consenting children ($N = 214$) were screened on their number knowledge. Children who received the lowest scores (22 out of a possible 44) on the *Number Sense Brief* (NSB; Jordan et al., 2010b) were identified as needing additional mathematics instruction. Children in our low-scoring group achieved below the 25th percentile, based on common items from an earlier version of the Number Sense Screener that has kindergarten norms from a range of social classes (Jordan et al., 2012).

Of the final sample, 59 of the children were girls (48%) and 65 were boys (52%). Twenty-two of the students were identified as African American (18%), 77 as Hispanic (63%), 22 as Caucasian (18%), and three as other races (2%), all by teacher report. Fifty-five percent of children were identified as English Language Learners (ELL) and enrolled in designated ELL kindergarten classrooms. Children from low-income backgrounds, as evidenced by their free and reduced lunch status, comprised 83% of the study population. Within each class, children were randomly assigned to one of three conditions: the mathematics vocabulary (SNC) intervention group, the number sense intervention control group (number sense), and the business-as-usual control group (control). Within each condition, children were randomly assigned to groups of four by school. Thus, children from the same class typically were not in the same small group. At three of the schools, all of the small groups met at the same time. In one school, the small groups occurred at various times.

Throughout the course of the study attrition was low ($n = 8$) and distributed across the groups. This included only two children from the SNC intervention, two children from the number sense intervention, and four children from the control group. In most of these cases, children moved out of the district or were chronically absent. Accordingly, the final study sample consisted of 124 children.

By setting the $\alpha = .05$ with 3 groups and 8 covariates (NSB pretest, BBCS-3:R pretest, BBCS-3:R SNC Intervention Words pretest, BBCS-3:R Fractions pretest, BBCS-3:R Math Signs/Symbols pretest, WJ-III Applied Problems pretest, WJ-III Calculation pretest, ELL Status), with power equal to the standard .80, given an effect size $f = .29$ —which is approximately a medium effect size using Cohen's (1988) criteria of $f = .25$ as medium and $f = .40$ as large effect sizes—the sample size was adequate to complete the statistical analyses.

Measures

Mathematics vocabulary—The *Bracken Basic Concept Scale-Third Edition: Receptive: Quantity* subtest (BBCS-3:R; Bracken, 2006a) is a standardized measure of children's mathematics vocabulary knowledge. The quantity subtest of the BBCS-3:R includes 43 items. The examiner shows the child a page with four different pictures and asks the child to point to the picture that answers the current question. The quantity subtest has high internal

consistency (split-half) for all of the age groups in the study ($> .90$) (Bracken, 2006b). In addition, the quantity subtest is highly correlated with the BBCS: 3- R Total Composite scores for all of the ages in the current study ($r = .86$).

The subset of 20 SNC intervention words present on the BBCS-3:R quantity subtest were used as a measure that closely aligned to the intervention. The SNC intervention words section of the BBCS-3:R supported additional analysis due to its strong reliability ($\alpha = .89$). In order to determine the particular types of words that children learned most effectively, conceptual categories within the BBCS-3:R quantity subtest including: relative quantity, volume, multiples, comparatives/superlatives, fractions (including part/whole), and mathematics signs/symbols were also used as a measure. Fractions (5 items) and mathematics signs/symbols conceptual categories (2 items) were examined, because they had the highest reliabilities ($\alpha = .70$ and $\alpha = .73$).

Number sense—The NSB (Jordan et al., 2010b) is an untimed test that takes approximately 20 minutes to administer. The NSB assesses counting, number recognition, number comparisons, nonverbal calculations, story problems, and number combinations. The items on the NSB are scored incorrect (0) or correct (1) with a total raw score of 44. The NSB is internally consistent, with a coefficient alpha of at least .80 during kindergarten (Jordan et al., 2009).

Mathematics achievement—The *Woodcock-Johnson III Tests of Achievement Normative Update Brief Battery/Form C* (WJ-III) Applied Problems and Calculation subtests (Woodcock, McGrew, & Mather, 2007) were used to assess mathematics achievement. In the Applied Problems subtest, the test administrator read problems aloud to children. Items required the use of mathematics reasoning (starting with simple counting questions, then orally presented story problems with pictures, and finally orally presented story problems without pictures). The Calculation subtest gauged computation in a written format with standard symbols (problems are presented horizontally and vertically, starting with $2 + 2 = \square$). For the ages of the children in the study, internal reliability is above .90 on the WJ-III (Woodcock et al., 2007).

Procedure

All children received their school's prescribed mathematics curriculum. While the SNC and number sense children took part in the respective interventions, the control group was involved in their classroom's regularly scheduled activities (e.g., specials or circle time). None of the children in any group was pulled from their regular mathematics instruction time.

After administering the pretest over the course of two weeks in November 2011, the interventions began in January 2012. Immediately following the intervention, children were post tested over the course of two weeks, beginning in March 2012. The delayed posttest was administered eight weeks after the immediate posttest, beginning in May 2012.

The 30-minute lessons were taught in small groups of four children per instructor three times per week over the course of eight weeks. Twelve highly-trained female education

undergraduate and graduate students (6 undergraduates and 6 graduates) carried out the intervention lessons. Instructors attended weekly meetings with the research team to discuss lesson procedures. No instructors post tested the children they instructed, and testers were not aware of the children's group membership during testing. Instructors only taught one type of intervention. Children in both the SNC and number sense interventions attended, on average, 22 out of the 24 possible sessions (92%).

Fidelity of Implementation

Lessons were scripted carefully to ensure fidelity of implementation. To be sure instructors followed the scripts, all lessons were audio recorded. After the lessons were concluded, three undergraduate research assistants checked a random sample of a third of the 24 lessons per instructor against the intervention scripts in order to determine the level of fidelity of intervention implementation. All instructors demonstrated over 90% fidelity on all of the scripts.

Storybook Number Competencies Intervention

The SNC intervention introduced mathematics vocabulary words to reinforce number concepts related to counting, number relations, and number operations (Cross, Woods, & Schweingruber, 2009). Before selecting words for the intervention, the CCSSM – Kindergarten (Common Core State Standards Initiative, 2010) were reviewed in order to identify appropriate mathematics conceptual vocabulary. After reviewing the kindergarten mathematics curricula and the standards, a total of 34 vocabulary words were selected for emphasis during instruction. (See table 1 for a list of the storybooks and intervention words.)

Intervention Content

The lessons were based on seven different children's storybooks with rich mathematics vocabulary not specifically designed to teach mathematics. The final week of instruction was reserved for review. Instruction for each book contained three separate sessions, taking place over the course of three days and covering approximately six vocabulary words.

The format of each lesson was modeled after the vocabulary learning elements of the *Text Talk: Level A* curriculum (Beck & McKeown, 2001b). These elements included dialogic reading and direct instruction of vocabulary words and also guided play activities. Vocabulary words were repeated in different books to reinforce children's understanding of the words in different contexts. (See table 2 for a description of lesson features.) Words were defined consistently across books to develop a shared meaning between the instructor and children (Evens, 2009).

The objective of each lesson was for students to identify and understand the vocabulary words in the context of the current story as well as in other everyday contexts, such as mathematics class. The instructor read the story while pointing out pictures and highlighting the comments of the students. During a second reading of the story, the instructor highlighted the day's vocabulary words by pointing them out and defining them. Next, the words were explicitly taught to the children. The words were defined within the context of the story. After defining the word, the instructor asked the children to find other examples of

the word in the story or to complete a short activity that relied on the definition of the word from the story.

Grounding the children's understanding of the words within the context of the story helped them be able to later transfer their understanding to other contexts (Beck & McKeown, 2007). Pairs of conceptually related words, such as "add" and "subtract", were taught together. Pairing related concepts allowed the children to see the relationships between ideas and differentiate between potentially difficult concepts.

The later part of the lesson was devoted to structured activities. First, mathematics instructional activities helped the children reinforce the key mathematics word(s) for the lesson. Each session included only one direct mathematics instruction activity; this was to ensure that the focus remained on vocabulary while still demonstrating how to use the words in mathematics contexts. For example, when learning about the words "add" and "subtract" during *McElligot's Pool* (Dr. Seuss, 1947), the children completed an activity focusing on story problems with fish. The instructor had a set of cards, with each card featuring a different colored fish. To begin the activity, the instructor said, "Let's practice adding with our Fish cards." Then, she gave one child five Fish cards and asked the child to tell a story by adding the fish. She gave an example first such as, "Two fish were swimming in McElligot's Pool. I will put down two fish cards. One more fish swam in from the ocean to join them. Now, I'll put down one more fish. Let's all add the fish to figure out how many are now in McElligot's Pool. $2 + 1 = 3$."

Lastly, the word-based activities used guided play to help the children understand how to use the words in other contexts. For example, children drew pictures of their "long" and "short" paths to school, like Harold from *Harold and the Purple Crayon* (Johnson, 1955). In this activity, children were given their own purple crayons to draw paths like Harold did in the story. They each drew their routes to school and explained their drawings to the others in the group.

At the end of each session, children played a word review game modeled after *Snakes & Ladders*. (See figure 1 for a sample of the game board.) The version of *Snakes & Ladders* used in the SNC intervention incorporated the principles of the Great Race Game, a linear number board game (Ramani & Siegler, 2008). However, instead of only focusing on counting on a number line, *Snakes & Ladders* incorporated learning the count sequence with vocabulary instruction. Each space on the game board corresponded with a word from the current lesson or previous lessons. When children landed on a space, they were required to answer the corresponding vocabulary question, as read to them by the instructor. However, as in the Great Race Game (Ramani & Siegler, 2008), children were required to count on from a number; for example, if a child spun a 2 when already on the number 4, he or she would say, "I am on 4. I spun a 2. I move to 5, 6." The researcher designed the *Snakes & Ladders* game board.

Number Sense Intervention

The number sense intervention used an established, evidence-based program aimed at improving children's counting, number relations, and number operations, without the use of storybooks (Dyson et al., 2013; Jordan et al., 2012).

Statistical Analyses

An experimental pretest, immediate posttest, and eight-week delayed posttest design was used. Dependent variables were 1) mathematics vocabulary, 2) number sense, and 3) general mathematics achievement. A series of one-way analyses of covariance (ANCOVA) were run to test mean gains between pretest and immediate posttest and pretest and delayed posttest, with pretest scores and ELL status used as covariates. Although students in the study were nested within intervention groups, the presence of non-significant, negligible intra-class correlation (ICC), defined as the proportion of group-level variance versus the total variance (Raudenbush & Bryk, 2002), suggested that there was no significant variance at the intervention group level, thus negating the use of hierarchical linear modeling techniques.

For each dependent variable, the pretest of that variable served as the covariate. Covariate(s) minimize the confounding factor of children's previous knowledge and reduce unexplained variance; as such, they increase the ability of the analyses to detect effects of the intervention (Field, 2009; Maxwell & Delaney, 2004). Preliminary analyses demonstrated that the demographic variables of gender and kindergarten start age were not significant predictors of any outcome. However, ELL status was a significant predictor of mathematics vocabulary and number sense at posttest and delayed posttest, denoting a difference in children's scores based on language status. Thus, ELL status was also included as a covariate in the analyses. Raw scores were used for all analyses. In addition to *p* values, effect sizes are reported using Hedges' *g*. Hedges' *g* is calculated in a similar manner as Cohen's *d*, except that Hedges' *g* adds a correction factor for smaller sample sizes (Hedges & Olkin, 1985). For Hedges' *g*, the Institute of Education Sciences: What Works Clearinghouse sets the criterion for effective educational interventions as having a value of *g* .25.

Results

Table 3 provides raw score means and standard deviations for the dependent variables (NSB, WJ-III, BBCS-3:R quantity subtest, and BBCS-3:R SNC intervention words, and BBCS-3:R conceptual categories) by group: SNC intervention, number sense intervention, and business-as-usual control. The *Ms* and *SDs* are separated by pretest, immediate posttest, and delayed posttest. For context, the mean percentile ranks (based on national age norms) by group and time of testing are presented for the BBCS-3:R and WJ-III subtests in table 4.

Mathematics Vocabulary

Table 5 provides *p* values and effect sizes for analyses where BBCS-3:R Quantity subtest pretest total scores and ELL status were used as covariates. Approaching significance at immediate posttest ($F(2, 119) = 2.890, p = .06$), the group means indicated that a trend where the SNC intervention group knew a greater number of mathematics vocabulary words

than their peers in the other groups. At delayed posttest, significant differences emerged between the SNC and the other groups ($F(2, 119) = 5.437, p = .006$); post hoc tests revealed that the children in the SNC group significantly outperformed the children in the number sense intervention ($g = .57, p < .05$) and the control group ($g = .51, p < .05$) on the BBCS-3:R.

SNC Intervention Words—Table 5 presents results using the SNC Intervention Words subset of the BBCS-3:R pretest scores as the covariate. Unlike the BBCS more generally, this measure was closely aligned with the intervention. At posttest, there was a significant group effect ($F(2, 119) = 3.932, p = .02$). The SNC group outperformed the number sense group but not the control group ($g = .57, p < .05$). At delayed posttest, there also was a significant group effect ($F(2, 119) = 6.763, p = .002$) with the SNC group performing significantly higher than both the number sense ($g = .61, p < .01$) and control groups ($g = .62, p < .05$).

The words that children learned in the SNC intervention were also important for their success in regular classroom mathematics instruction. For example, as evidenced by their early inclusion in the classroom mathematics curriculum, *Math Connects* (Altieri et al., 2009), “more than” and “less than” were foundational concepts in the kindergarten mathematics curriculum. Understanding the meaning of “more than” and “less than” gives children a way to describe, compare, and estimate numerical quantities. Although *Math Connects* introduces these concepts in the first weeks of kindergarten at pretest, only 15% of children across all groups demonstrated an understanding of “more than,” and 6% understood “less than”. However, by posttest, 27% of children in the control group, 23% of the number sense children, and 38% of children in the SNC group correctly identified “more than.” For “less than,” 25% of control group children, 16% of number sense, and 43% of SNC children understood the concept by posttest. By delayed posttest, 62% of the children in the SNC group showed an understanding of “more than,” while only 35% of the control group and 43% of the number sense group answered the item correctly. Similarly, 50% of the SNC children demonstrated an understanding of “less than,” while only 33% of the control group and 31% of the number sense group showed a similar understanding. These findings demonstrated the ability of the children in the SNC group to continue a strong pattern of growth from pretest to delayed posttest regarding vocabulary words that enabled them to describe and manipulate quantities. The other two groups also grew from posttest to delayed posttest, but not as much as the SNC group. However, the large numbers of children who still could not master the items by delayed posttest highlight the continued struggle of children with early numeracy difficulties to understand mathematics vocabulary.

Conceptual categories—The mean scores for the BBCS-3:R conceptual categories are displayed in table 3. The words in the fractions conceptual category were part, whole, divided, half, and piece. At posttest, there was a significant group effect for words in the fractions conceptual category ($F(2, 119) = 3.311, p = .04$). However, post hoc tests revealed that significant differences existed only between the SNC group and the number sense group ($g = .54, p < .05$). At delayed posttest, there was also a significant group effect ($F(2, 119) = 11.070, p = .001$) demonstrating that the SNC group outperformed both the number sense

group ($g = .86, p < .001$) and the control group ($g = .78, p < .001$) in early fractions words concepts.

ANCOVAs using intervention concepts from the mathematics signs/symbols conceptual category (i.e., the ability to understand the relationship between the concept of add and the + sign) revealed a significant group effect at posttest ($F(2, 119) = 11.440, p = .001$). (See table 5.) Post hoc tests demonstrated that the SNC group outperformed both the number sense group ($g = .82, p < .001$) and the control group ($g = .74, p < .001$). At delayed posttest, the group effect held ($F(2, 119) = 8.825, p = .001$) with the SNC group still outperforming both the number sense ($g = .66, p < .001$) and control groups ($g = .80, p < .001$).

Number Sense and General Mathematics Achievement

The SNC children did not show statistically significant gains relative to the other groups on the NSB or WJ-III as indicated in Table 6. At immediate posttest, there was a marginally significant group effect for the NSB ($F(2, 119) = 3.004, p = .053$). The children in the number sense intervention outperformed the control group on the NSB ($g = .21, p < .05$). This value of g does not meet the IES criteria for educational effectiveness. No group effects were found at any time point for the WJ-III Applied Problems subtest. However, significant group effects were present at immediate posttest for the Calculation subtest ($F(2, 119) = 5.969, p = .003$). The children in the number sense intervention outperformed both the children in the control group ($g = .59, p < .01$) and children in the SNC intervention ($g = .58, p < .05$).

Discussion

The goal of the current study was to examine effects of a mathematics vocabulary intervention on low-income kindergartners' mathematics vocabulary and number knowledge. The work stepped beyond the scope of the current storybook intervention literature to build a bridge between specific mathematics conceptual vocabulary and mathematics instruction.

SNC Intervention Effects on Mathematics Vocabulary

The original hypothesis of the study, that reliable group differences would be present on the BBCS-3:R quantity subtest, was confirmed. The SNC group outperformed the other groups at delayed posttest. This finding suggests that the SNC intervention contributed something over and above a novelty effect, since the children in the SNC group outperformed the business-as-usual group—who did not receive special treatment—and the number sense group—who did receive special treatment. Although there were not significant group differences at immediate posttest, the data suggested a trend in that direction. Similar results were found on a subset of the BBCS-3:R that assessed the words taught in the intervention, except that significant differences emerged between the SNC and number sense groups at immediate posttest. For a general picture of gains, examination of the age-based national percentile ranks on the BBCS-3:R quantitative vocabulary measure showed that, on average, the SNC children grew from 14.72 to 36.69 percentile points over the course of the study

compared to smaller gains for the number sense group (from 14.68 to 23.21) and the control group (from 15.69 to 20.80).

In terms of background variables, ELL status was included as a covariate for all analyses. In particular, English Language Learners, regardless of group, did not perform as well on the BBCS-3:R as their non-ELL peers at any time point. English Language Learners may not have had a strong enough initial foundation of general English vocabulary support the same level of development of more difficult mathematics conceptual words as their peers. However, there were similar growth trajectories from pretest to delayed posttest between the ELL (11 points) and non-ELL children (11.7 points) in the SNC intervention. This finding suggests that ELL children were able to benefit from the specific mathematics vocabulary instruction in the SNC intervention, perhaps because they had not been previously exposed to these types of words.

Although for different reasons, children with specific language impairment (SLI) also struggle with learning language and math. Research on children with SLI suggests that many children with language difficulties are able to understand the concepts of “more” and “less” (Fazio, 1996) and grasp the principles behind the use of “plus” and “minus” (Donlan, Cowan, Newton, & Lloyd, 2007). This finding that these types of concepts are accessible to children, regardless of their initial language understanding, supports the current study’s finding that ELL and non-ELL children in the SNC intervention grew similarly in their mathematics vocabulary knowledge.

Conceptual categories—Children with early numeracy difficulties benefitted from multiple, rich exposures to mathematics vocabulary words to grasp the concepts the words represent. For example, by the end of the intervention, only the SNC group had received instruction regarding fraction concepts (“part,” “whole,” “half,” “divide,” “piece”) and mathematics signs/symbols (“+,” “−”), and the children in the SNC group outperformed the other two groups at immediate posttest on the measures of both conceptual categories. However, children in the SNC group outperformed both the number sense and control group children on the BBCS-3:R fractions and mathematics signs/symbols conceptual categories at delayed posttest. Children in the SNC group were given initial opportunities to explore fraction concepts and mathematics signs/symbols through the intervention, which may have been reinforced by regular classroom instruction in the same concepts. It is possible that the experiences with the words during the SNC intervention helped children to continue to build their knowledge of fraction words and mathematics signs/symbols.

Interestingly, through conducting observations, Jennings and colleagues (1992) found that children receiving mathematics storybook instruction used significantly more words in the categories of time/money (e.g., “last,” “nickel,” etc.) and comparisons (e.g., “more than,” “less than,” etc.) than their peers in the control group. The BBCS-3:R contains a similar conceptual category, Comparatives/Superlatives, featuring words such as “more than” and “less than.” There were no significant group differences in this category in our study. However, the Jennings et al. study did not measure children’s word knowledge at pre- and posttest, so it is impossible to know whether or not children in the experimental group

already knew these words before the start of the study. Also, the authors did not specify if the children had to use a word correctly in order for it to count as an instance of word usage.

SNC Intervention Effects on Number Sense and General Mathematics Achievement

Previous mathematics storybook interventions (i.e., Hong, 1996; Jennings et al., 1992; Young-Loveridge, 2004) generated statistically significant gains in children's early mathematics knowledge. However, in the present study, the SNC children did not perform significantly better than the other two groups on any of the mathematics outcomes. At posttest, the number sense group outperformed the control group but not the SNC group on the Number Sense Brief. On the WJ-III mathematics achievement test, there were no group effects on applied problems, but on calculation, the number sense children performed better than the other groups at posttest.

To understand why there were not many group differences on the mathematics measures, we examined *Math Connects* (Altieri et al., 2009), the kindergarten curriculum that was used with all of the study children. Many of the number concepts taught in both the number sense and SNC interventions—including the count sequence, more than/less than, before/after—were featured in *Math Connects* during the intervention time span. By the end of the year, *Math Connects* had also provided instruction in completing addition and subtraction story problems and calculations. This is likely to have accounted for the good gains in numeracy made by all groups. Interestingly, in previous studies with demographically similar children (Dyson et al., 2013; Jordan et al. 2012), there were larger and more sustained effects between number sense intervention children and controls. Since that time, however, teachers reported that they had implemented more targeted number interventions in their classrooms. Thus, it is likely that all of the early numeracy difficulties children in the present study were receiving extra numeracy help. Even so, children in the SNC group had the advantage of making sustained gains in mathematics vocabulary, which can provide a beneficial foundation for formal math instruction in first grade.

With regard to the previous literature, only one of the mathematics storybook interventions (Young-Loveridge, 2004) was conducted with children demonstrating early numeracy difficulties, but the study did not include any standardized mathematics measures. One result of including only children with early numeracy difficulties in the current study was that even the most advanced students rarely scored more than 20 raw score points (out of a possible 63) on the WJ-III Applied Problems subtest. Thus, there may have been some floor effects, which made the test less sensitive to the effects of the interventions. The combination of improved classroom mathematics instruction and the focus on children with low initial levels of numeracy knowledge may explain the lack of significant differences between the groups on some of our mathematics achievement measures.

Limitations and Future Research

The relatively short duration of the interventions may have limited experimental children's gains. Moreover, some successful intervention studies (e.g., Fuchs et al., 2005) have featured one-on-one instruction. Although more labor intensive, one-on-one instruction allows to children to focus on the material being presented without the distractions of other

children and to receive immediate and tailored feedback from the instructor. In fact, attention and executive function skills have been shown to mediate children's early numeracy development (Hassinger-Das, Jordan, Glutting, Irwin, & Dyson, 2014). The present study, however, was designed to mimic real-world school situations where schools and schools may have limited resources for providing one-on-one tutoring.

Because the participants in our three study groups received the same classroom mathematics instruction, the external validity of the research is limited to this curriculum. As such, the effect of both interventions may have been due to the interaction of the intervention curriculum and the classroom mathematics curriculum, instead of the sole effect of the intervention instruction. It is possible that the effectiveness of the *Math Connects* (Altieri et al., 2009) curriculum, which is generally aligned with the CCSSM – Kindergarten, contributed to non-significant differences among the three groups on some of the mathematics measures. Future studies might examine the effectiveness the SNC intervention in conjunction with kindergarten mathematics curricula that follow a different skill progression.

The possible presence of a “reverse” novelty effect—the effect of not receiving any special treatment—also may have affected our results. For example, it is possible that the business-as-usual control children resented the fact that their classmates got to leave the classroom three times a week to play math and word games. These feelings could have resulted in less enthusiasm or indifferent behavior at posttest. As such, business-as-usual children's post test scores may have underestimated their proficiency.

In the SNC intervention, vocabulary instruction was directed primarily at improving children's mathematics vocabulary, with a secondary emphasis on number concepts. Future research might combine more explicit numeracy help, which was successful in the number sense intervention group, with vocabulary instruction to help children apply their new “math words” to numerical tasks. Another avenue for investigation would be to compare children's gains on mathematics storybook interventions versus a more explicit approach to teaching the words.

In the present study, we considered children who performed poorly on a number sense screener as a single group. Future research should consider individual differences in children's numeracy when developing and carrying out interventions (Dowker & Sigley, 2010; Holmes & Dowker, 2013). For example, our interventions could be refined to target specific areas of weakness (and strengths) for individual children (e.g., primary difficulties with the language of mathematics vs. fundamental difficulties with nonverbal number competencies).

In conclusion, our SNC intervention holds promise for developing high-risk kindergartners' mathematics vocabulary and conceptual knowledge in a rich storybook context. The approach is accessible to both teachers and paraprofessionals. Caregivers could also implement storybook math at home. Of course, the most effective interventions will continue to provide support as children progress beyond the kindergarten year (Clements & Sarama, 2009).

References

- Altieri, MB.; Balka, DS.; Day, R.; Gonsalves, PD.; Grace, EC.; Krulik, S.; Vielhaber, K. Math Connects: K. Columbus, OH: Macmillan/McGraw-Hill; 2009.
- Anderson RC, Nagy WE. The vocabulary conundrum. *American Educator*. 1992 Winter;14–18:44–46.
- Baroody AJ, Cibulskis M, Lai M, Li X. Comments on the use of learning trajectories in curriculum development and research. *Mathematical Thinking and Learning*. 2004; 6:227–260.10.1207/s15327833mtl0602_8
- Baroody AJ, Feil Y, Johnson AR. An alternative reconceptualization of procedural and conceptual knowledge. *Journal for Research in Mathematics Education*. 2007; 38:115–131.
- Beck IL, McKeown MG. Text talk: Capturing the benefits of read-aloud experiences for young children. *The Reading Teacher*. 2001a; 55:10–20.
- Beck, IL.; McKeown, MG. Text Talk: Robust Vocabulary Instruction: Level A. New York: Scholastic, Inc; 2001b.
- Beck IL, McKeown MG. Increasing young low-income children's oral vocabulary repertoires through rich and focused instruction. *The Elementary School Journal*. 2007; 107:251–271.10.1086/511706
- Beck, IL.; McKeown, MG.; Kucan, L. Bringing words to life: Robust vocabulary instruction. New York: The Guilford Press; 2002.
- Biemiller A, Boote C. An effective method for building meaning vocabulary in primary grades. *Journal of Educational Psychology*. 2006; 98:44–62.10.1037/0022-0663.98.1.44
- Bracken, BA. Bracken Basic Concept Scale-Third Edition: Receptive. San Antonio, TX: The Psychological Corporation; 2006a.
- Bracken, BA. Bracken Basic Concept Scale-Third Edition: Receptive: Examiner's manual. San Antonio, TX: The Psychological Corporation; 2006b.
- Bryant DP, Bryant BR, Roberts G, Vaughn S, Pfannenstiel KH, Porterfield J, Gersten R. Early numeracy intervention program for first-grade students with mathematics difficulties. *Exceptional Children*. 2011; 78:7–23.10.1086/499748
- Carpenter TP, Hiebert J, Moser JM. The effect of instruction on children's solutions of addition and subtraction word problems. *Educational Studies in Mathematics*. 1983; 14:55–72.10.1007/BF00704702
- Case, R. The development of conceptual structures. In: Damon, W.; Kuhn, D.; Siegler, R., editors. *Handbook of child psychology Vol. 2: Cognition, perception and language*. 5. New York: John Wiley & Sons, Inc; 1998. p. 745-800.
- Case R, Okamoto Y, Griffin S, McKeough A, Bleiker C, Henderson B, et al. The role of central conceptual structures in the development of children's thought [Monograph]. *Monographs of the Society for Research in Child Development*. 1996; 61:1–295.10.2307/1166077 [PubMed: 8657164]
- Clark, RE. How much and what type of guidance is optimal for learning from instruction?. In: Tobias, S.; Duffy, TM., editors. *Constructivist instruction: Success or failure?*. NY: Routledge; 2009. p. 158-183.
- Clements, DH.; Sarama, J. Learning and teaching early math: The learning trajectories approach. New York, NY: Routledge; 2009.
- Cohen, J. Statistical power analysis for the behavioral sciences. 2. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc; 1988.
- Common Core State Standards Initiative. Common core state standards for mathematics. 2010. Retrieved from http://www.corestandards.org/assets/CCSSI_Math%20Standards.pdf
- Coyne MD, McCoach DB, Kapp S. Vocabulary intervention for kindergarten students: Comparing extended instruction to embedded instruction and incidental exposure. *Learning Disability Quarterly*. 2007; 30:74–88.
- Coyne MD, Simmons DC, Kame'enui EJ, Stoolmiller M. Teaching vocabulary during shared storybook readings: An examination of differential effects, Exceptionality. 2004; 12:145–162.

- Coyne MD, Zipoli RP, Ruby MF. Beginning reading instruction for students at risk for reading disabilities: What, how, and when. *Intervention in School and Clinic*. 2006; 41:161–168. [10.1177/10534512060410030601](https://doi.org/10.1177/10534512060410030601)
- Cross, CT.; Woods, TA.; Schweingruber, H., editors. *Mathematics learning in early childhood: Paths toward excellence and equity*. Washington, D.C: The National Academies Press; 2009.
- Donlan C, Cowan R, Newton EJ, Lloyd D. The role of language in mathematical development: evidence from children with specific language impairments. *Cognition*. 2007; 103:23–33. [PubMed: 16581052]
- Dowker A, Sigley G. Targeted interventions for children with arithmetical difficulties. *British Journal of Educational Psychology, Monograph Series II*. 2010; 7:65–81.
- Seuss. *McElligot's pool*. New York, NY: Random House; 1947.
- Dyson N, Jordan NC, Glutting J. A number sense intervention for low- income kindergartners at risk for math difficulties. *Journal of Learning Disabilities*. 2013; 46:166–181. [10.1177/0022219411410233](https://doi.org/10.1177/0022219411410233) [PubMed: 21685346]
- Engelmann, S.; Osborn, J. *Language for Learning*. Columbus, OH: McGraw-Hill; 1999.
- Evens, H. Listening to mathematics students: Is our language the same?. In: Houssart, J.; Mason, J., editors. *Listening Counts: Listening to young learners of mathematics*. Stoke-on-Trent, UK: Trentham Books; 2009.
- Falconer, I. Olivia. New York, NY: Simon & Schuster, Inc; 2000.
- Fazio B. Mathematical abilities of children with specific language impairments: a follow-up study. *Journal of Speech and Hearing Research*. 1996; 39:839–849. [PubMed: 8844563]
- Feigenson L, Dehaene S, Spelke ES. Core systems of number. *Trends in Cognitive Sciences*. 2004; 8:307–314. [PubMed: 15242690]
- Field, A. *Discovering statistics using SPSS*. 3. London, UK: Sage; 2009.
- Fuchs LS, Compton DL, Fuchs D, Paulsen K, Bryant JD, Hamlett CL. The prevention, identification, and cognitive determinants of math difficulty. *Journal of Educational Psychology*. 2005; 97:493–513.
- Gelman R, Butterworth B. Number and language: How are they related? *Trends in Cognitive Sciences*. 2005; 9:6–10. [PubMed: 15639434]
- Gersten R, Jordan NC, Flojo JR. Early identification and interventions for students with mathematics difficulties. *Journal of Learning Disabilities*. 2005; 38:293–304. [PubMed: 16122059]
- Ginsburg, HP.; Baroody, AJ. *Test of early mathematical ability*. Austin, TX: ProEd; 1983.
- Ginsburg, M. *Two greedy bears*. New York, NY: Aladdin Paperbacks; 1998.
- Halberda J, Taing L, Lidz J. The development of “most” comprehension and its potential dependence on counting ability in preschoolers. *Language, Learning, and Development*. 2008; 4:99–121.
- Han M, Moore N, Vukelich C, Buell M. Does play make a difference? How play intervention affects the vocabulary learning of at-risk preschoolers. *American Journal of Play*. 2010; 3:82–104.
- Harris, J.; Golinkoff, RM.; Hirsh-Pasek, K. Lessons from the crib for the classroom: How children really learn vocabulary. In: Neuman, SB.; Dickinson, DK., editors. *Handbook of early literacy research*. New York, NY: Guilford Press; 2010. p. 49-66.
- Hart, B.; Risley, RT. *Meaningful differences in the everyday experience of young American children*. Baltimore, MD: Paul H. Brookes; 1995.
- Hassing-Das B, Jordan NC, Glutting J, Irwin C, Dyson N. Domain-general mediators of the relation between kindergarten number sense and first-grade mathematics achievement. *Journal of Experimental Child Psychology*. 2014; 118:78–92. [PubMed: 24237789]
- Hedges, LV.; Olkin, I. *Statistical methods for meta-analysis*. New York, NY: Academic Press; 1985.
- Hirsh-Pasek, K.; Golinkoff, RM.; Singer, D.; Berk, L., editors. *A mandate for playful learning in preschool: Presenting the evidence*. NY: Oxford University Press; 2009.
- Holmes W, Dowker A. Catch Up Numeracy: a targeted intervention for children who are low-attaining in mathematics. *Research in Mathematics Education*. 2013; 15:249–265.
- Hong H. Effects of mathematics learning through children's literature on math achievement and dispositional outcomes. *Early Childhood Research Quarterly*. 1996; 11:477–494.

- Jennings CM, Jennings JE, Richey J, Dixon-Krauss L. Increasing interest and achievement in mathematics through children's literature. *Early Childhood Research Quarterly*. 1992; 7:263–276.
- Jordan, NC.; Fuchs, LS.; Dyson, N. Early number competencies and mathematical learning: Individual variation, screening, and intervention. In: Cohen Kadosh, R.; Dowker, A., editors. *Oxford handbook of numerical cognition*. Oxford, UK: Oxford University Press; in press
- Jordan NC, Glutting J, Dyson N, Hassinger-Das B, Irwin C. Building kindergarteners' number sense: A randomized controlled study. *Journal of Educational Psychology*. 2012; 104:647–660.10.1037/a0029018 [PubMed: 25866417]
- Jordan NC, Glutting J, Ramineni C. The importance of number sense to mathematics achievement in first and third grades. *Learning and Individual Differences*. 2010a; 20:82–88. [PubMed: 20401327]
- Jordan NC, Glutting J, Ramineni C, Watkins MW. Validating a number sense screening tool for use in kindergarten and first grade: Prediction of mathematics proficiency in third grade. *School Psychology Review*. 2010b; 39:181–185.
- Jordan NC, Levine SC. Socioeconomic variation, number competence, and mathematics learning difficulties in young children. *Developmental Disabilities Research Reviews*. 2009; 15:60–68.10.1002/ddrr.46 [PubMed: 19213011]
- Justice LM, Meier J, Walpole S. Learning new words from storybooks: An efficacy study with at-risk kindergarteners. *Language, Speech, and Hearing Services in Schools*. 2005; 36:17–32.
- Kirschner PA, Sweller J, Clark RE. Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*. 2006; 41:75–86.
- Kleemans T, Segers E, Verhoeven L. Cognitive and linguistic precursors to numeracy in kindergarten: Evidence from first and second language learners. *Learning and Individual Differences*. 2011; 21:555–561.
- Klibanoff RS, Levine SC, Huttenlocher J, Vasilyeva M, Hedges LV. Preschool children's mathematical knowledge: The effect of teacher "math talk". *Developmental Psychology*. 2006; 42:59–69. [PubMed: 16420118]
- Lansdell JM. Introducing young children to mathematical concepts: Problems with 'new' terminology. *Educational Studies*. 1999; 25:327–333.10.1080/03055699997837
- Lesh, R.; Post, T.; Behr, M. Representations and translations among representations in mathematics learning and problem solving. In: Janvier, C., editor. *Problems of representation in the teaching and learning of mathematics*. Hillsdale, NJ: Lawrence Erlbaum Associates; 1987. p. 33–40.
- Marulis LM, Neuman SB. The effects of vocabulary intervention on young children's word learning: A meta-analysis. *Review of Educational Research*. 2010; 80:300–335.
- Maxwell, SE.; Delaney, HD. *Designing experiments and analyzing data: A model comparison perspective*. 2. Mahwah, NJ: Erlbaum; 2004.
- Mayer RE. Should there be a three-strikes rule against pure discovery learning?: A case for guided methods of instruction. *American Psychologist*. 2004; 59:14–19.10.1037/0003-066X.59.1.14 [PubMed: 14736316]
- Mix, KS.; Huttenlocher, J.; Levine, SC. *Quantitative development in infancy and early childhood*. New York, NY: Oxford University Press; 2002.
- Mol SE, Bus AG, de Jong MT. Interactive book reading in early education: A tool to stimulate print knowledge as well as oral language. *Review of Educational Research*. 2009; 79:979–1007.
- Moss J, Case R. Developing children's understanding of the rational numbers: A new model and an experimental curriculum. *Journal for Research in Mathematics Education*. 1999; 30:122–147.
- National Council of Teachers of Mathematics. *Principles and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics; 2000.
- National Research Council. *Mathematics learning in early childhood: Paths toward excellence and equity*. Washington, DC: National Academies Press; 2009.
- Nurss, JR.; McGaurvan, ME. *Metropolitan readiness test*. 5. San Antonio, TX: The Psychological Corporation; 1986.
- Pape SJ, Tchoshanov MA. The role of representation(s) in developing mathematical understanding. *Theory into Practice*. 2001; 40:118–127.

- Purpura DJ, Hume LE, Sims DM, Lonigan CJ. Early literacy and early numeracy: The value of including early literacy skills in the prediction of numeracy development. *Journal of Experimental Child Psychology*. 2011; 110:647–658. [PubMed: 21831396]
- Putambekar S, Hubscher R. Tools for scaffolding students in a complex learning environment: What have we gained and what have we missed? *Educational Psychologist*. 2005; 40:1–12.10.1207/s15326985ep4001_1
- Ramani GB, Siegler RS. Promoting broad and stable improvements in low-income children's numerical knowledge through playing number board games. *Child Development*. 2008; 79:375–394. [PubMed: 18366429]
- Raudenbush, SW.; Bryk, AS. Hierarchical linear models: Applications and data analysis methods. 2. Thousand Oaks, CA: Sage; 2002.
- Roskos K, Burnstein K. Assessment of the design efficacy of a preschool vocabulary instruction technique. *Journal of Research in Childhood Education*. 2011; 25:267–287.10.1080/02568543.2011.580041
- Sandhofer CM, Smith LB. Learning color words involves learning a system of mappings. *Developmental Psychology*. 1999; 35:668–679. [PubMed: 10380858]
- Schleppegrell, MJ. Language in mathematics teaching and learning. In: Moschkovich, JN., editor. *Language and mathematics education: Multiple perspectives and directions for research*. Charlotte, NC: Information Age Publishing; 2010. p. 73-112.
- Skemp, RR. *The psychology of learning mathematics*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc; 1987.
- Vanderlinde LF. Does the study of quantitative vocabulary improve problem-solving? *The Elementary School Journal*. 1964; 65:143–152.
- Van De Walle, JA. *Elementary and middle school mathematics: Teaching developmentally*. 6. Boston, MA: Pearson Education, Inc; 2007.
- Wasik BA, Bond MA. Beyond the pages of a book: Interactive book reading in preschool classrooms. *Journal of Educational Psychology*. 2001; 93:43–50.
- Waxman SR, Markow PB. Words as invitations to form categories: Evidence from 12- to 13-month old infants. *Cognitive Psychology*. 1995; 29:257–302. [PubMed: 8556847]
- Whitehurst GJ, Falco FL, Lonigan CJ, Fischel JE, DeBaryshe BD, Valdez-Menchaca MC, Caulfield M. Accelerating language development through picture book reading. *Developmental Psychology*. 1988; 24:552–559.
- Woodcock, RW.; McGrew, KS.; Mather, N. *Woodcock-Johnson III Normative Update: Tests of Achievement*. Itasca, IL: Riverside; 2007.
- Young-Loveridge J. Effects on early numeracy of a program using number books and games. *Early Childhood Research Quarterly*. 2004; 19:82–89.

Figure 1. Snakes & Ladders game board.

Table 1

Storybooks and Vocabulary Words

Title	Lesson Numbers^I	Author	Vocabulary Words
<i>Two Greedy Bears</i>	1 – 3	Mirra Ginsburg (1998)	Divide, Equal, Part/Whole, Piece, Bigger/Smaller, Half
<i>McElligot's Pool</i>	4 – 6	Dr. Seuss (1947)	With/Without, Same, Short/Long, Bigger/Smaller, Add/Subtract
<i>Caps for Sale</i>	7 – 9	Esphyr Slobodkina (1940)	First/Second/Third, Above/Below, Before/After
<i>Harold and the Purple Crayon</i>	10 – 12	Crockett Johnson (1955)	Straight, Short/Long, None, More than/Less than, Left(over)
<i>Olivia</i>	13 – 15	Ian Falconer (2000)	Enough, Before/After, Closer to, Add/Subtract
<i>Mike Mulligan and His Steam Shovel</i>	16 – 18	Virginia Lee Burton (1939)	Some, As many as, Least/Greatest, Part/Whole, Add/Subtract
<i>The Snowy Day</i>	19 – 21	Ezra Jack Keats (1962)	Equal, Before/After, Add/Subtract, More/Less, Pair

Note.

^IThe total intervention consisted of 24 lessons (3 per book). The final 3 lessons (22 – 24) were reserved for review of the words from the previous seven books.

Table 2**SNC Intervention Lesson Components Per Book**

Book Session¹	Component
All sessions	Read the story <ul style="list-style-type: none"> • Dialogic reading technique engaging children with the text
Session 3	Vocabulary assessment <ul style="list-style-type: none"> • Children explain the words in the context of the story
Sessions 1 & 2	Introduce words/vocabulary instruction <ul style="list-style-type: none"> • Second reading of the story highlighting the new words • Direct explanation of the meaning of the words • Children locate other examples of the word in the story or complete a short activity that relies on the definition of the word from the story
All sessions	Direct mathematics instruction <ul style="list-style-type: none"> • Activities that apply the new words to mathematical contexts
All sessions	Word-based activity <ul style="list-style-type: none"> • Guided play activities that apply the words to other contexts outside of the story
Session 3	Connect the words to story comprehension <ul style="list-style-type: none"> • Children demonstrate an understanding of how the words relate to their comprehension of the story
All sessions	Play <i>Snakes & Ladders</i> <ul style="list-style-type: none"> • Game reinforces vocabulary learned throughout the lesson(s)

Note.

¹The instruction for each of the seven books was comprised of 3 separate sessions.

Table 3

Raw Score Means and Standard Deviations by Group and Time

Measures	Items	Pretest			Posttest			Delayed		
		M	SD		M	SD		M	SD	
NSB Total	45									
SNC		13.14	4.31	26.95	8.06	30.05	7.67			
Number sense		13.64	4.67	28.64	8.43	29.90	9.11			
Control		14.75	3.73	26.90	7.98	30.03	8.66			
BBCS-3:R Quantity Total	43									
SNC		13.81	6.96	22.26	9.97	25.14	7.92			
Number sense		12.52	7.84	17.64	8.65	20.36	8.69			
Control		12.95	8.45	19.63	8.80	21.10	7.68			
Intervention Words	20									
SNC		5.76	3.12	10.29	5.67	11.95	4.93			
Number sense		5.17	3.96	7.36	4.35	8.95	4.76			
Control		5.28	3.78	8.45	4.72	9.12	4.05			
Conceptual Categories Fractions	5									
SNC		1.83	1.10	3.14	1.52	3.74	1.35			
Number sense		1.62	1.21	2.36	1.32	2.57	1.35			
Control		1.80	1.18	2.63	1.35	2.73	1.22			
Mathematics Signs/Symbols	2									
SNC		0.02	0.15	0.67	0.85	0.70	0.85			
Number sense		0.05	0.30	0.12	0.39	0.21	0.56			
Control		0.03	0.15	0.15	0.48	0.15	0.43			
WJ-III Applied Problems										
SNC		8.31	2.90	11.31	2.71	12.17	2.64			
Number sense		8.45	2.56	11.45	2.46	11.79	2.66			
Control		8.72	2.18	11.10	2.22	12.20	1.84			
WJ-III Calculation										
SNC		0.33	0.90	3.05	2.50	4.76	3.14			
Number sense		0.34	0.91	4.84	3.57	5.12	3.44			

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Measures	Pretest			Posttest			Delayed		
	M		SD	M		SD	M		SD
Control	0.42		0.71	3.10		1.98	4.40		2.79

Note. BBCS-3:R = Bracken Basic Concepts Scale-3: Receptive Quantity subtest, SNC = Storybook Number Competencies intervention, NSB = Number Sense Brief, WJ-III = Woodcock-Johnson-III, M = Mean, SD = Standard deviation.

Table 4

Percentile Rank Means and Standard Deviations on the BBCS-3:R and WJ-III Subtests by Group and Time

Measure	Pretest		Posttest		Delayed	
	M	SD	M	SD	M	SD
BBCS-3:R Quantity						
SNC	14.72	14.05	34.03	29.53	36.69	27.46
Number sense	14.68	21.38	18.65	24.62	23.21	25.36
Control	15.69	18.57	22.55	22.69	20.80	25.13
WJ-III Applied Problems						
SNC	30.21	25.50	46.81	24.83	47.62	24.49
Number sense	31.05	22.50	46.18	23.04	42.10	22.75
Control	31.35	21.45	42.53	20.77	46.68	20.16
WJ-III Calculation						
SNC	3.76	17.02	44.31	34.88	55.07	30.53
Number sense	5.09	18.83	56.55	37.64	56.24	30.67
Control	7.88	20.77	47.40	31.61	51.83	27.08

Note: BBCS-3:R = Bracken Basic Concepts Scale-3; Receptive Quantity subtest, WJ-III = Woodcock-Johnson-III, SNC = Storybook Number Competencies intervention, M = Mean, SD = Standard deviation.

Table 5

ANCOVA Post Hoc Results Evaluating Intervention Effectiveness for Mathematics Vocabulary with Covariate(s)

Dependent Variable	Covariate(s) Total BBBS-3:R Quantity Pretest/ELL Status		
	SNC vs. NS (ES)	SNC vs. Control (ES)	NS vs. Control (ES)
	<i>g</i>	<i>g</i>	<i>g</i>
Total BBBS-3:R Quantity post	<i>ns</i>	<i>ns</i>	<i>ns</i>
Total BBBS-3:R Quantity delayed	.57*	.51*	<i>ns</i>
Covariate(s) Intervention Words Pretest/ELL Status			
	SNC vs. NS (ES)	SNC vs. Control (ES)	NS vs. Control (ES)
	<i>g</i>	<i>g</i>	<i>g</i>
Intervention Words post	.57*	<i>ns</i>	<i>ns</i>
Intervention Words delayed	.61**	.62*	<i>ns</i>
Covariate(s) Fractions Pretest/ELL Status			
	SNC vs. NS (ES)	SNC vs. Control (ES)	NS vs. Control (ES)
	<i>g</i>	<i>g</i>	<i>g</i>
Fractions post	.54*	<i>ns</i>	<i>ns</i>
Fractions delayed	.86***	.78***	<i>ns</i>
Covariate(s) Math Signs/Symbols Pretest/ELL Status			
	SNC vs. NS (ES)	SNC vs. Control (ES)	NS vs. Control (ES)
	<i>g</i>	<i>g</i>	<i>g</i>
Math Signs/Symbols post	.82***	.74***	<i>ns</i>
Math Signs/Symbols delayed	.66***	.80***	<i>ns</i>

Note.

*
 $p < .05$,

**
 $p < .01$,

 $p < .001$.

Table 6

ANCOVA Post Hoc Results Evaluating Intervention Effectiveness for Number Sense and General Mathematics Achievement with Covariate(s)

Dependent Variable	Covariate(s) Total NSB Pretest/ELL Status		
	NS vs. SNC (ES)	SNC vs. Control (ES)	NS vs. Control (ES)
	<i>g</i>	<i>g</i>	<i>g</i>
Total NSB post	<i>ns</i>	<i>ns</i>	.21*
Total NSB delayed	<i>ns</i>	<i>ns</i>	<i>ns</i>
Covariate(s) WJ-III Applied Problems Pretest/ELL Status			
	NS vs. SNC (ES)	SNC vs. Control (ES)	NS vs. Control (ES)
	<i>g</i>	<i>g</i>	<i>g</i>
WJ-III Applied Problems post	<i>ns</i>	<i>ns</i>	<i>ns</i>
WJ-III Applied Problems delayed	<i>ns</i>	<i>ns</i>	<i>ns</i>
Covariate(s) WJ-III Calculation Pretest/ELL Status			
	NS vs. SNC (ES)	SNC vs. Control (ES)	NS vs. Control (ES)
	<i>g</i>	<i>g</i>	<i>g</i>
WJ-III Calculation post	.58*	<i>ns</i>	.59*
WJ Calculation delayed	<i>ns</i>	<i>ns</i>	<i>ns</i>

Note.

* $p < .05$,

** $p < .01$,

*** $p < .001$.